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ARTIFICIAL DAYLIGHT.*

BY

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IN the fourteenth century the Glover's Company, of London, decreed that "no one shall sell his goods by candle light." When Tyrian purple was the staple cargo of the galleys of Phœnicia, it is safe to say that the buyers of that day early learned by experience to make no purchases by torchlight. Certainly it has long been known among those whose business it is to work with colors that daylight and "yellow candle light" are wide apart, not only in appearance, but also in their effect upon colors. It comes, nevertheless, as a surprise to many to learn how numerous are the industries whose working hours depend upon daylight. Color printing and lithography, dyeing, the painting and viewing of pictures, tobacco sorting, the grading of sugar and flour, the sorting of precious stones, the matching of colored fabrics, the inspection of meats and delicate chemical analysis—these are a few having need for daylight at all hours, to say nothing of the surgeon and the dentist.

Among women a knowledge of the defects and pitfalls of artificial light is more general than among men, doubtless because

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the prevailing fashions call for color in feminine attire. In a big store any day, almost any minute, one may see prospective purchasers of dress goods carrying pieces of goods, or having them carried, to the more or less distant windows to learn their true daylight appearance. For a dress must not look well merely by the artificial light over the counter, but out of doors as well, and frequently is good by one and inharmonious or ugly by the other.

The fact that, as a rule, artificial light is greatly different in appearance from daylight need be merely noted at this point. Most artificial lights are more or less yellow as compared with the light of the sun or sky. The difference is usually very great, as any one can convince himself by comparing the two side by side under conditions of approximate equality of brightness for the two. For instance, if two shadows of a pencil are formed side by side by the two kinds of light, such as a tungsten lamp and the sky, the shadow illuminated by artificial light appears orange yellow; that by the sky, deep blue by contrast. Ordinarily we do not appreciate this difference because we do not see the two lights together, and because, if the artificial light is not too strongly colored, the eye by the process of adaptation will in large measure adjust itself to the new distorted color scale—just as a man in walking against the wind unconsciously leans forward. There is a large and interesting problem here for the physiologist and the psychologist to answer: in what way and how much the use of artificial light so different in quality from the light under which the race has been developed may affect the eye and the mind. Certain it is that artificial light is not an unmixed blessing. To its increased use is popularly ascribed many eye troubles. Then, too, many of our habits as social animals seem intimately connected with the use of artificial light. Whether it be the glitter and heat of our ballroom lights, or the odor and dimness of our midnight oil, that work their characteristic stimulation, benefits, depression, or ocular injury, or whether these are to be ascribed to their color, is a problem of interest, but here we shall concern ourselves almost entirely with the severely practical question of producing artificial daylight for industrial purposes.

What is daylight? is the inevitable question, for it is at once evident that the setting sun, a clear blue sky, and a "white"

cloud are markedly different. So, too, the light reflected into our buildings from snow, grass, foliage, from earth, brick pavements, or gray asphalt is far from being a uniform thing. Daylight is, in fact, quite variable in color, a fact which has led professional color matchers to search for the most constant kind of daylight. This they have decided to be the light from a clear north sky. To the eye this is unmistakably blue in color, hence the problem of producing daylight is not necessarily the same as that of producing "white" light.

In order to answer the question: "What is daylight?" it becomes necessary to measure color. We shall, therefore, first pay some heed to the scientific measurement of color. We shall then apply the methods of color measurement to our present illuminants, natural and artificial, and so learn how they differ from each other.

Various ways of producing artificial daylight will present themselves as a result of this study and will be discussed. Next we shall investigate the problem of why and how colors change in appearance in going from one kind of light to another. From this we shall be led to formulate the necessary characteristics of a color-matching artificial daylight. Some account of the practical achievement of artificial daylight, its various forms and its characteristics, will follow. Then a little space will be devoted to a study of the distribution of natural daylight out of doors and in rooms, and the possibility of our ultimately copying, at a not prohibitive expense, both the color and the distribution of natural daylight.

COLOR MEASUREMENT.

There are two distinct methods of color measurement. The first is by analysis of the light radiations into their elements and then quantitative measurement of these elements. The second is by analysis according to the effects on the visual apparatus. Properly speaking, the first method is not color measurement at all, since, as will be seen, a color-blind observer or a thermometer, if sensitive enough, may be used to make the measurements. Nevertheless, our problem is an indeterminate one without such measurements, so that they must be treated in detail.

As every one knows, light may be analyzed or dispersed by means of a prism or grating. Sunlight, when so dispersed, gives

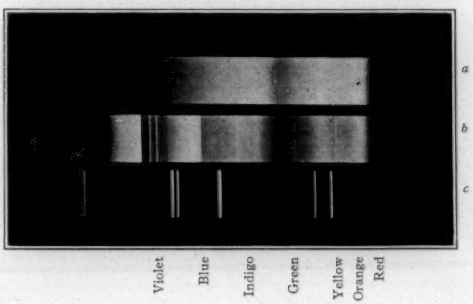
the rainbow or solar spectrum with its numerous colors, of which the principal ones are red, orange, yellow, green, indigo, blue, and violet. Any complete study of color must be a study of colored light, since it is only by seeing colored light that we appreciate objects as being colored. The color of an object is, in fact, determined by the completeness with which it reflects or transmits the light which falls upon it. It owes its color to the existence of that color in the light illuminating it. A red glass is red because it transmits the red of the spectrum. For this reason the whole story of an illuminant's behavior as a revealer of color is laid bare when once the light of the illuminant is analyzed completely. These analyses may be considered in two parts—qualitative and quantitative. Qualitatively we note important differences in the spectra of different light sources. Sunlight, for instance, gives a continuous spectrum with no noticeable breaks from red to violet. A candle gives a similar spectrum, but one which will give us some difficulty in seeing the blue and violet portions, unless we arrange our prism device (spectroscope) in a way favorable to bring considerable light to the eye. A carbon arc light shows a continuous spectrum, but one on which are superposed bright violet lines or bands. A nitrogen vacuum tube exhibits several isolated broad bands of colored light. A carbon dioxide vacuum tube shows numerous fine lines and bands nearly filling the entire spectrum. A mercury arc, representing the extreme from the continuous spectrum, exhibits merely isolated bright lines of light. In short, in the incandescent mercury vapor only comparatively few vibrations are represented, which when communicated to the ether produce light waves of those few wave-lengths only (Fig. 1).

Considerable information bearing on our special problem is furnished by this merely qualitative survey. It is at once evident that a light totally lacking in any color of the spectrum, such as the mercury arc, which is lacking in red, is not capable of showing that particular color in an object. But this qualitative knowledge must be supplemented by quantitative measurements before it has any real use. Such measurements are usually made by the spectrophotometer, which is, in brief, a spectroscope so arranged that each color may be compared in intensity with the same colored light from a chosen standard light. In place of a standard light it is much preferable to reduce the results to an absolute

standard,—*i.e.*, to obtain the intensity of the radiation at each wave-length as indicated by the heating effect. The values which are given here have been so reduced as to show these energy values, as though they had been obtained by the use of a bolometer or thermocouple at the observing slit of the spectrometer.

Fig. 2 plots in the form of curves the relative intensities throughout the spectrum of certain representative illuminants, including sunlight and blue sky, these latter being the mean of a number of observations by different people. The curves as drawn equal .59μ, which is merely a matter of convention, since the

FIG. 1.



Spectra of representative light sources. (*a*) Continuous spectrum of the Welsbach mantle; (*b*) continuous spectrum with superposed bands, carbon arc; (*c*) line spectrum of the mercury arc.

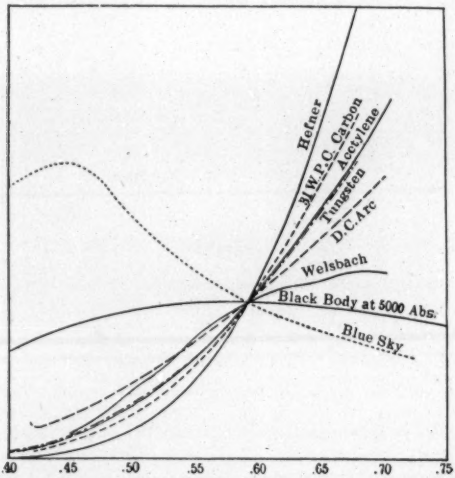
actual relative intensities of the lights are not involved. As a matter of fact, this convention practically means that the lights compared are at nearly the same luminosity.

An examination of these curves yields interesting information. Practically all the common artificial illuminants differ from daylight in having an excess of red, orange, and yellow radiations, with a corresponding deficiency in blue and violet. They lie together in an entirely different family from the varieties of daylight. The latter differ in the blue on this scale by less than the factor two, whereas the ratio between day and the artificial lights is from six to twelve. The physical explanation of this lies in the fact that the common illuminants are incandescent solids at comparatively low temperatures, such as 1500–2500° K., while

sunlight approximates in color an incandescent solid or black body at 5000° K. The practical effects of this characteristic of the common illuminants, such as the incandescent electric lamp, the Welsbach mantle, the gas flame, etc., are two: First, their general yellow color, and, second, their different effects on colored objects. This latter peculiarity will be treated presently.

The second method of color measurement must now be considered. This is derived through color-mixture experiments. It

FIG. 2.



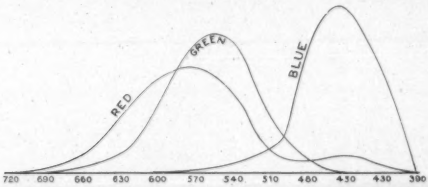
Relative intensities through the spectrum of certain representative illuminants.

owes its significance to the important fact that colors may look exactly alike which are, nevertheless, composed of quite different radiations, as indicated by the spectroscope. For instance, a mixture of red light and green light produces a yellow which is indistinguishable in hue from a true spectroscopic yellow,—*i.e.*, a color showing nothing but a small region of the spectrum around the yellow. Similarly a mixture of yellow light and blue light produces a white indistinguishable from one in which all the spectrum colors are present. Red and bluish green constitute another

part of these "complementaries," as they are called. The most interesting set of mixture colors, however, are red, green, and blue, for it has been found that from these three may be made not only white, but all the colors of the spectrum, and hence all the colors formed by the addition and subtraction of these; that is, all the colors of nature. It must be clearly understood, however, that these color matches are subjective; that is, they look the same, but of course on analysis with the spectroscope they at once show their composite character.

Now this characteristic of red, green, and blue light has led to these colors being called "primaries." They constitute the smallest number of colors out of which all the others may be produced. As such they have had a notable part in making color photography possible. Here we are more interested in the fact

FIG. 3*a*.



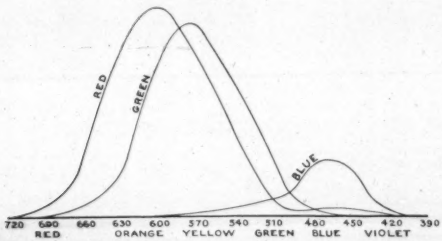
Color sensations in white light.

that these phenomena of color mixture furnish a method of measuring and representing colors as they appear to the eye, irrespective of their composition.

Taking the spectrum of white light as our standard, it is possible by a series of experiments to determine the quantities of red, green, and blue necessary to match each of the other spectrum colors. Curves may thus be plotted representing these facts, and are called color-mixture curves of the spectrum. This has been done, and it has been found that the true primaries are a certain red, green, and blue a little purer and more saturated than any ordinarily found in the spectrum. These experimentally indicated true primaries are called the primary or fundamental sensations. Fig. 3*a* shows their distribution in the spectrum, where the units are chosen such that equal quantities of the three sensations give white.

A color may now be specified in terms of but three quantities, instead of a dozen or more, as is necessary with the spectrophotometer. White is equal quantities red, green, and blue sensation; yellow is so much red sensation and so much green, as may be read off the curves. A complex color such as that of an illuminant may be evaluated by multiplying its spectrophotometric value at each wave-length (as compared with white light) by the values of the three sensations at the corresponding wave-lengths and then integrating the curves. Thus the values derived by the use of the spectrophotometer may be translated into sensation values. This transformation process is indicated by the curves of Fig. 3*b*, in the case of a carbon incandescent lamp.

FIG. 3*b*.



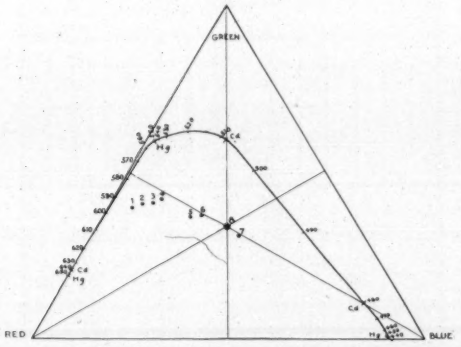
Color sensations in incandescent carbon lamp light.

Still another way to obtain the sensation values is by actually making mixtures of red, green, and blue light to match the color under measurement. If one knows the sensation values of the red, green, and blue lights mixed, the results may be at once translated into terms of the fundamental sensations. Some results of transformations to color sensations from both kinds of measurements of color are shown in the color triangle, Fig. 4.

The results of measurements in terms of color sensations lend themselves to an elegant and useful diagrammatic representation in what is called the Maxwell color triangle, which we shall have occasion to use later. This triangle is shown in Fig. 4, where the three fundamental sensations are indicated at the three vertices, white at the centre and the various spectrum colors in their

appropriate positions around the triangle. A certain property of an equilateral triangle is here utilized; namely, that the sum of the vertical distances of any point from the three sides is equal to the altitude. If, then, the three sensations which constitute a color be represented in such units that their sum is the altitude of the triangle, every color finds a place in it. White, being equal parts of the three sensations, lies at the centre.

FIG. 4.



Color triangle, showing positions of spectrum colors and representative illuminants.

1. Hefner.
2. Carbon.
3. Tungsten.
4. Welsbach.
5. D. C. arc.
6. Afternoon sun.
7. CO_2 tube.
8. Whole light.

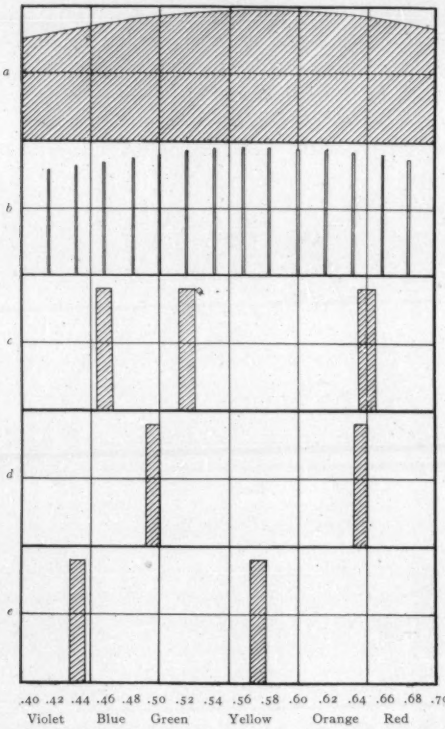
An interesting and valuable property of the triangle is that mixtures of two colors lie on the line joining them. Thus the yellow lies on the line joining red and green. White lies on the line joining a large number of pairs of colors, the "complementaries" met with above. We can then read off from this triangle what colors are to be mixed to produce any others, among them white.

The various sensation values for different illuminants are plotted in the triangle of Fig. 4. This plot again shows how most artificial illuminants differ from white toward yellow, as they are much nearer the yellow of the spectrum than the white centre.

METHODS OF MAKING WHITE LIGHT.

As a result of the study of color measurement several methods of artificially making white light present themselves. First and

FIG. 5.



Various ways of making white light. (*a*) Continuous spectrum; (*b*) a large number of lines or bands; (*c*) a mixture of red, green and blue, (*d*) a mixture of red and blue-green, (*e*) a mixture of yellow and blue.

most obvious, theoretically, is the production of an illuminant that has the same distribution of intensity throughout the spectrum

as a chosen daylight standard. For instance, if the standard be taken as the color of an incandescent solid at 5000° C. absolute, the direct way to make artificial daylight would be to heat a solid to such a temperature. This, of course, we know is impossible with our present facilities for high temperatures and our known refractory substances. Some form of selective radiation, as from certain oxides as yet unstudied, or from gases under electrical discharge, must then be looked to as a possible means of securing directly, without prohibitive temperature, the desired energy distribution in the spectrum.

A second method is to subtract, as by a process of absorption, those radiations in an illuminant which are present in excess over daylight. The manner of accomplishing this theoretically is indicated by Fig. 11, where an ordinary artificial illuminant (excess in red, orange, and yellow) is to be made to match daylight. Starting with a point on the extreme blue of the spectrum, progressively greater portions of the illuminant's radiations are to be absorbed, as indicated by the area of the curve above the cross-hatched portion. Assuming the absorption performed, there remains a spectrum identical in every respect to the standard white light.

A third method of producing white light is indicated by the color-mixture experiments; namely, by the mixing of two or three colors respectively complimentary. Fig. 5 shows an illustration of how white light might be made up of (*a*) a continuous spectrum, (*b*) a large number of lines or bands, (*c*) a mixture of red and blue green, (*d*) a mixture of yellow and blue, and (*e*) a mixture of red, green, and blue, the proper quantities of each being taken so that the total of each fundamental sensation is in every case the same.

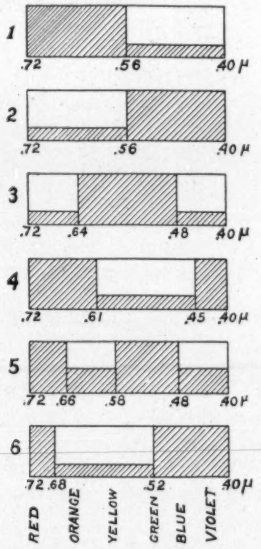
With these various means at our disposal it becomes necessary to establish criteria upon which their relative merits may be decided. Among such criteria are efficiency and suitability for color matching. The latter requirement is the most important one here, and will next be considered.

THE REQUIREMENTS OF A COLOR-MATCHING ILLUMINANT.

What is the relationship between the color of an illuminant and the color of the illuminated object? An answer in one

simple case is straightway evident. If the illuminant lacks the spectrum rays which by reflection from a surface constitute the color of the surface, then the illuminant obviously is useless for revealing whether two such non-reflecting surfaces are the same color or not under other and more usual illuminants. But if all the spectrum colors are present, though with varying intensity,

FIG. 6.



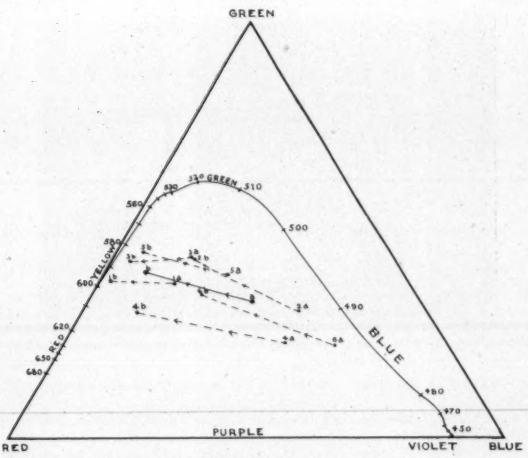
Spectral composition of certain arbitrary colors; reflecting power of surfaces or transmissions of absorbing media.

it is not so easy to answer the question at issue. We must have recourse to the methods of measurement above outlined.

Let us take a representative color, such as is to be found in a dyed fabric. With a spectrophotometer determine its reflecting power at each wave-length of the spectrum. If we multiply the values obtained by the values of the sensation curves in two

illuminants under study, we arrive at the resultant sensations as excited by the light reflected from the fabric under the two different lights. These values may then be tabulated or plotted in a color triangle showing the change in the color of the surface under the different illuminants. On carrying through this operation for the set of arbitrary colors shown in Fig. 6, under daylight and under carbon lamp light, the color triangle data of Fig. 7 were obtained. It is to be seen that, while pure spectrum

FIG. 7.

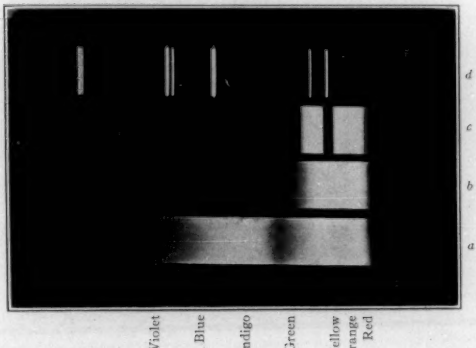


Change in color produced by change from daylight (*a*) to carbon incandescent lamp illumination (*b*).

colors change not at all (since they have no various spectral components to be altered in relative intensity), the colors nearer white are bodily shifted in hue. Purples become reds, greens turn to yellows, and so on. This illustrates the change of color appearance, which is very marked, for the kind of illuminants compared, with purples and lavenders (which become ruddy), blues (which become black), yellows (which appear less strongly colored). But the question of color matching is the paramount one. If two colors match under one illuminant, will they match

under another? The answer is evident if we consider the two possible kinds of matches. If we have two yellows, identical as to reflecting power through the spectrum, obviously they will continue to match under any illuminant, since both will be affected alike. But suppose one of them is a mixture of red and green, the other a spectrum yellow. Under white light they are identical in appearance. But when they are placed under a light different in composition, such as a carbon incandescent lamp, the red ele-

FIG. 8.



Cause of change of appearance of colors of different composition when viewed under different illuminants. (*a*) Continuous spectrum light source; (*b*) and (*c*) two yellow solutions which appear exactly alike when illuminated by light source (*a*); (*d*) line spectrum. Solution (*c*) absorbs one of the principal lines of this spectrum and consequently appears different in color from (*b*).

ment of the composite color is unduly accentuated, the green element insufficiently brought out, and the resultant appearance is not the same as that of the simple yellow. This difference may be shown numerically by the use of the color sensation curves and the color triangles. It is illustrated for an extreme case by the spectrograms of Fig. 8. Here are shown (*a*) a continuous spectrum light (Welsbach mantle), (*b*) and (*c*) the spectra of two yellow solutions which match perfectly under this light, and (*d*) a discontinuous spectrum (mercury arc). Note that the absorption band in the second yellow falls exactly over the yellow mercury line; the mercury arc light viewed through this solution

is bright green; through the other solution it is yellow. The two solutions look exactly alike by one light, totally different by the other.

It is obvious, from these considerations, that if an artificial daylight is to behave toward all kinds of colors exactly as does real daylight, it must not only look like daylight, but must be identical with it, wave-length by wave-length through the spectrum.

THE PRACTICAL ACHIEVEMENT OF ARTIFICIAL DAYLIGHT.

Before proceeding to an account of various artificial daylights let us here review briefly the pertinent facts about daylight and color. We have seen that daylight is variable, but that it always lies in a class apart from the usual artificial light sources, which latter are in general of a yellow color. We have seen how color may be exactly measured, and have learned that the same color appearance may be produced in several ways. Several theoretical ways of producing artificial daylight have been described. Finally, by investigating the changes in the apparent color of objects under different colors of light, we have been led to formulate the essential characteristic of artificial daylight; namely, it must not only look like daylight, but also be like it, as shown by an analysis of the spectrum.

In approaching the practical side of the problem it becomes necessary to choose a standard for daylight, and it becomes necessary to know what degree of approximation to the last-named criterion is sufficient for practical purposes. It is also necessary to pay attention to the matter of efficiency—the artificial daylight must not be prohibitive in cost.

The standard of white light adopted by the writer is derived from the mean of a large number of spectrophotometric determinations of sunlight quoted above, into which an additional factor has been introduced. It is always desirable to connect any standard with other standards; to depend not on a set of numerical values, but on some simple mathematical expression which may be developed by the introduction of a few constants. It appears, for instance, that the white light standard mentioned has to within the limits of accuracy of its determination the distribution of intensity through the spectrum of a perfect incan-

descent solid or black body at 5000° C. absolute; a distribution immediately calculable from the laws of black body radiation. So much for a scientific standpoint. In commercial practice another fact has had to be given weight; namely, professional color matchers have chosen as their standard light the blue north sky. It is difficult to change the customs of experts, and so it became practically necessary to supply a blue sky standard. For this the spectrophotometer values given in Fig. 2 serve as a basis.

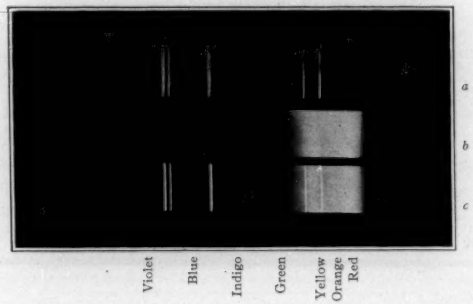
How closely is it necessary in practice to approximate the exact spectrum distribution of daylight? Very closely indeed, but not so exactly as to be prohibitively difficult, for this reason: that all ordinary colored objects and coloring materials have rather long diffuse spectra; they are not isolated, sharply defined spectrum colors. Consequently, if such gaps and irregularities of the artificial daylight spectrum are bridged over by the reflection spectrum of the color illuminated, they will not be noted. For instance, an illuminant whose spectrum consisted of twenty-five or thirty equally spaced lines would probably behave excellently as a color-matching light, provided, of course, their intensity was closely that of the daylight spectrum at each point. An expert with a knowledge of the spectrum and of the kind of coloring media used in the arts can make up critical colors having several maxima of reflecting power in the spectrum, colors which match under one light but not under another, and from the accumulated experience of the practical dyer other colors may be found of similar difficult character. The behavior of these colors under an artificial daylight in its experimental stages provides valuable information and guidance.

The question of efficiency will be considered in connection with each of the three kinds of artificial daylight described below.

The first kind of artificial daylight postulated as possible is a light source that has naturally the same spectrum distribution of intensity as daylight. An incandescent black body at 5000° C. absolute would have this distribution, but such a temperature is entirely beyond our present means. The same distribution could be obtained at much lower temperatures if we had available a selectively radiating substance which would give out a comparatively small amount of invisible heat radiation and have a much greater emissivity at the blue end of the spectrum than at the red. Such a substance is not yet known, but the materials used in the

Welsbach mantle approximate the characteristics to a degree which incites us to further study of these oxides. Another possible way of achieving this spectrum distribution is through non-temperature radiations, as, for instance, by the passage of a current of electricity through a rarefied gas which would radiate at a sufficient number of wave-lengths in the right proportion. Such an artificial daylight has been found in the radiation from the carbon dioxide vacuum tube, which under the name of the Moore tube has been developed commercially and has deservedly been used to considerable extent for color-matching

FIG. 9.



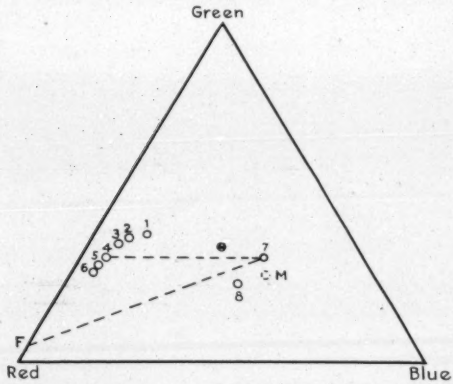
Additive production of artificial daylight. (*a*) Mercury arc spectrum; (*b*) tungsten lamp spectrum; (*c*) combination of mercury arc and tungsten lamp light to make a white light.

work. Its spectrum consists of many fine lines and bands, together giving the color of a light blue sky and of reasonable uniform intensity. The Moore tube is, however, comparatively inefficient and demands an expensive installation of alternating current and transformer to produce high potential—drawbacks which have prevented its extensive use.

The second kind of artificial daylight I wish to treat of here is one of interest from the standpoint of color measurement and theory. So far as concerns the question of color matching, this particular daylight,—namely, the one made by matching pairs of colors to look like daylight,—is chiefly of importance as illustrating the pitfalls to be avoided.

A property of the color triangle above referred to is that colors lying on opposite sides of a line passing through the centre of the triangle (white) mix to produce all colors lying on that line, among them white. Consequently, if two happen to lie thus on opposite ends of a line through the centre of the color triangle, it should be possible to make a white-appearing mixture. Examination of the color triangle, Fig. 10, shows that the mercury vapor arc lies opposite the tungsten lamp. Consequently, if

FIG. 10.



Illustrating white-appearing lights made by combining the mercury arc with other illuminants; 1, 2 and 3, Welsbach mantles; 4, tungsten lamp; 5 and 6, tantalum and carbon lamps; 7, mercury arc; *F*, color of fluorescent reflector; 8, mixture of mercury light from lamp and reflector (*M*) with *F*.

these two illuminants act together the appearance should be that of white light. Such is, in fact, the case. White-appearing light can be so produced at an efficiency somewhere between that of the two constituents, and white light of this constitution is to be found in several places. The term "additive" production of artificial daylight may be applied to this process to distinguish it from the other process presently to be described as "subtractive." This particular "additive" daylight, and others which are apt to be produced experimentally in efforts to make a true artificial daylight, are characterized by their failure to show up colors in their true daylight appearance. The reason for the

failure of this particular combination is easily seen from the spectrograms of Fig. 9, where the tungsten lamp spectrum is shown, with its deficiency in blue; the mercury arc spectrum, deficient in red, and the combination of the two. The latter is characterized by long gaps and irregularities. The mercury arc-tungsten combination is not, therefore, suited for one use to which it has been mistakenly put; namely, the illumination of picture galleries.

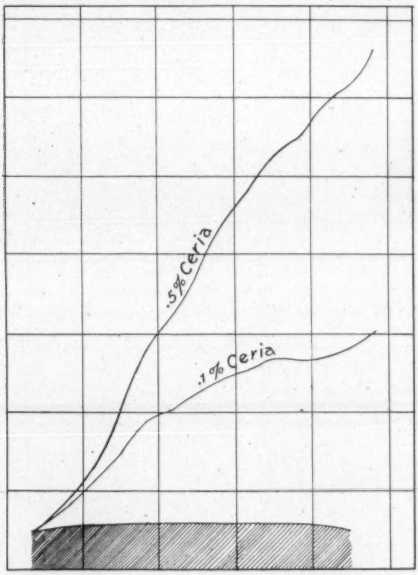
Another example of this additive method of producing white light is furnished by the Cooper-Hewitt lamp with fluorescent reflector. The fluorescent substance—rhodamine—is of a color approximately complementary to the hue of the mercury arc, as is shown in the color triangle of Fig. 10, where the fluorescent light is shown at *F*, the mercury arc at 7, and the "white" light at 8. This is not exactly on the line joining 7 and *F*, because the mercury arc light reflected from the rhodamine reflector is deficient in green. The real mixture is between *F* and *M*. It will be seen that the resultant color is a purplish-white (below centre of the triangle). This light is, unfortunately, not suited for delicate color matching, because its spectrum is merely the mercury lines with an orange-red band added. Large portions of the spectrum are missing.

The next, and on the whole the most important, method of producing artificial daylight is the subtractive one; that is, the subtraction by absorption of those radiations which an illuminant emits in excess over daylight.

By way of detailed explanation let us now carry through the various steps in the practical production of such an artificial daylight. Let us take as our illuminant to be transformed to daylight the Welsbach mantle, which, because of its nearer approach to whiteness than the usual incandescent solids, especially recommends itself for the purpose. The first step is to determine its distribution of intensity throughout the spectrum and compare it to that of daylight. At once cognizance must be taken of the fact that the color (intensity distribution) of a mantle depends upon the composition. A pure thoria mantle is much whiter than a mantle of pure ceria, the light of the latter being, in fact, deep orange-yellow. Fig. 11 shows the energy distribution of two typical mantles, containing .25 per cent. and

.50 per cent. ceria respectively, each compared with daylight under such conditions that the intensity at the extreme blue end of the spectrum is equal. When these data are so plotted the space between the mantle curves and the daylight curve represents light which must be absorbed. It is obvious that the whiter

FIG. 11.

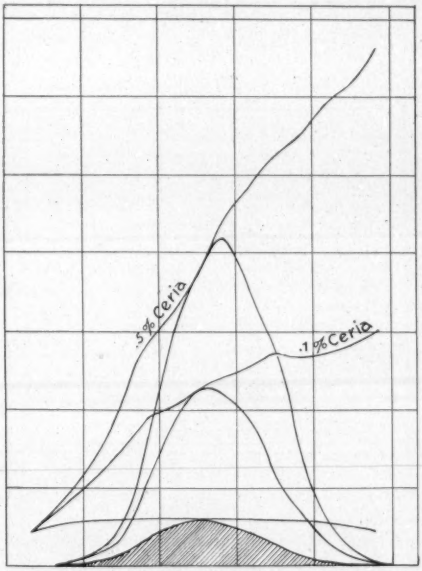


Typical Welsbach mantles compared spectrophotometrically with daylight.

the mantle (*i.e.*, the smaller the percentage of ceria) the less light must be absorbed in order to leave daylight. As yet, however, the amount of this absorption is not expressible in useful comparative units. It is necessary to express this in terms of luminosity. This is done by replotting the data of Fig. 11, multiplying the value at each wave-length by the relative brightness of

that kind of radiation as is done in Fig. 12. Now the area of the "white" luminosity curve, compared to the area of the mantle curve, gives us at once the relative amount of light left after the subtraction process. This ratio I have called the "daylight efficiency." Its value for mantles of various percentages of ceria

FIG. 12.

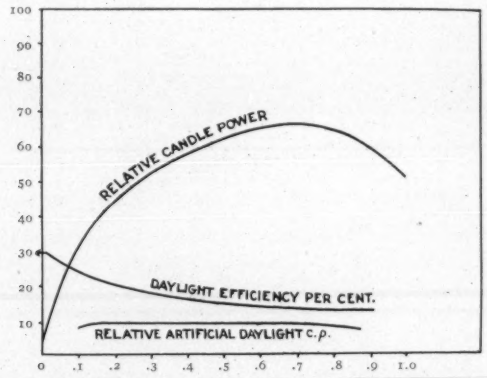


Calculation of daylight efficiencies of different mantles.

is plotted in curve *a*, Fig. 13. Other things being equal, it is clear that the mantle with no ceria should be chosen. But other things are not equal, for with varying percentages of ceria the candle-power of a mantle changes, rising from a minimum for the pure ceria one to a maximum for a mixture of 99 per cent.

ceria and 1 per cent. of thoria, then again decreasing as the ceria content is increased. This curve of relative candle-power is also shown in Fig. 13. It is obvious that the product of curves *a* and *b* will give the total daylight efficiency of all mantles when screened to make artificial daylight. This product is shown in curve *c*, interesting as showing that mantles through quite a range of composition—from .25 per cent. to .7 per cent. ceria—can yield the same efficiency of artificial daylight. Above .7 per cent. ceria the efficiency drops off rapidly. This efficiency is only

FIG. 13.



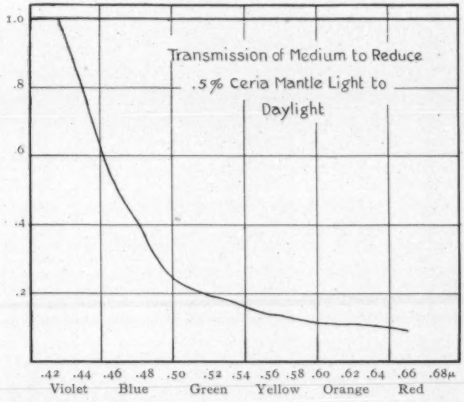
Total efficiency calculations for mantles of various compositions.

about 15 per cent., showing that artificial daylight is necessarily an expensive product when thus secured.

Having chosen a mantle to be screened, the next question is that of absorbing media. What is the absorption needed? Putting it in terms of transmission it is this: The transmission at each wave-length must be the ratio of the daylight intensity to the artificial light intensity when so represented that the value is unity for the extreme end of the spectrum. The transmission required to transform the light of the Welsbach mantle of .5 per cent. ceria to "white" (black body at 5000° C. absolute) is

shown in Fig. 14. It appears that the absorbing medium indicated is of general blue color. The next step is to study the various available absorbing media. These are practically reduced to two: first, colored glass, and, second, dyes which may be incorporated in gelatine or some similar transparent carrier. No single glass or combination of glasses at present on the market possesses the absorption called for. Cobalt blue glass, which is the first thought of every one, has several irregular bands, not a uniformly increasing transmission toward the blue end of the spectrum. Copper

FIG. 14.

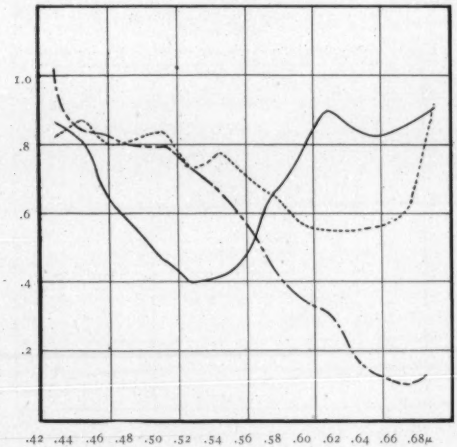


Transmission of medium to reduce light from .5 per cent. ceria mantle to daylight.

glass, which is blue-green in color, has a gradual absorption, but is too green. The great advantages of glass over dyed gelatine are its permanence and the possibility of working it into all shapes, from flat sheet to spherical enclosure. Still, dyes have the one advantage that they provide an enormous number of absorptions of both broad and narrow types. Some representative transmissions are shown in Fig. 15. The bands and deficiencies of glasses can almost always be filled in by properly chosen dyes, although many dyes are not at all permanent, which reduces very materially the number available.

It has been found possible to make a practical combination of copper glass in sheet form with a dyed gelatine layer on a separate sheet, which accomplishes the purpose admirably, using dyes of great permanence. The commercial device is shown in Fig. 16. It consists of a small booth, closed at back and sides, in order that stray light from other light sources may not enter and mix with the daylight. Samples of cloth, tobacco, etc., are held under

FIG. 15.



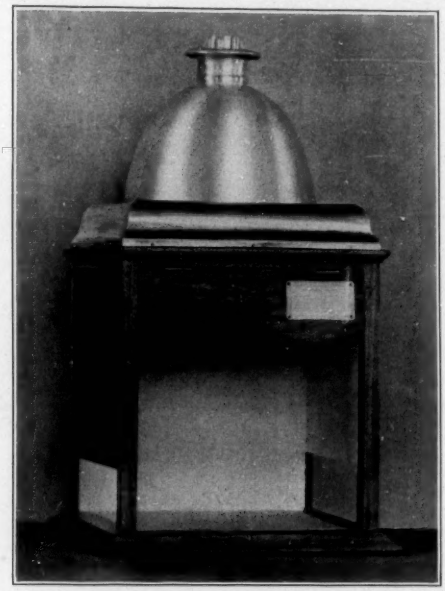
Transmission curves of representative glasses and dyes.

the glasses, and the result is identical with daylight. The spectrophotometer intensity curve is shown in Fig. 17, both for a .7 per cent. ceria mantle, which gives the sunlight color, and for a .25 per cent. ceria mantle, which gives the north light used by dyers and color matchers.

With the .25 per cent. upright mantle more than 20 ft. candles illumination is obtained on the working plane, while with a large inverted mantle the figure is multiplied by four—in either case sufficient for color-matching purposes. The absorption of light by the glasses is about 90 per cent. The device has been

worked out in the booth form partly because the expense of lighting large areas would be excessive, were there not some good reason for so doing, which often there is not, and partly to educate the user to exclude stray light of other colors which

FIG. 16.



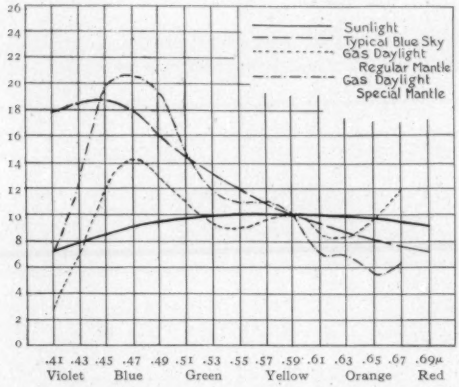
Color-matching booth.

would distort his color values. These devices are now being used extensively in silk mills, cigar factories, department stores, etc.

A limitation to this form is its lack of flexibility, caused by the necessity for using dyed gelatine, which can be laid down only on a flat plate. The extreme desirability of effecting the entire absorption through glass has long been apparent, and in

the Research Laboratories of The United Gas Improvement Company a small experimental glass plant has been actively engaged in the problem of producing such glass. All known coloring oxides have been studied, and Mr. Edw. J. Brady, in charge of this particular research, has recently succeeded in producing a true daylight glass. This glass will shortly be available for gas and other illuminants, and will make artificial daylight as easy to produce as any other artificial light—necessarily at a larger cost, to be sure; but in many cases this larger cost will be an insignificant item compared with the twelve or more additional working hours furnished by artificial daylight.

FIG. 17.



Spectrophotometric curves of natural and artificial daylight.

Before leaving this subject of the production of light having a daylight color, one of the methods of using the absorbing medium claims attention. Colored objects, it must be remembered, owe their color to the effect on the light incident upon and reflected from them. Now, it is immaterial whether the light is subjected to the day-color producing absorption before or after its incidence on the colored object. Except for considerations of convenience, the absorbing glasses could just as

well be placed vertically in front of the booth in Fig. 16, and the colored samples placed in the direct light of the illuminant. Advantage is taken of this alternative possibility in the construction of the daylight spectacles, shown in Fig. 18. Built with a perfectly light-excluding hood, these may be worn by the surgeon

FIG. 18.

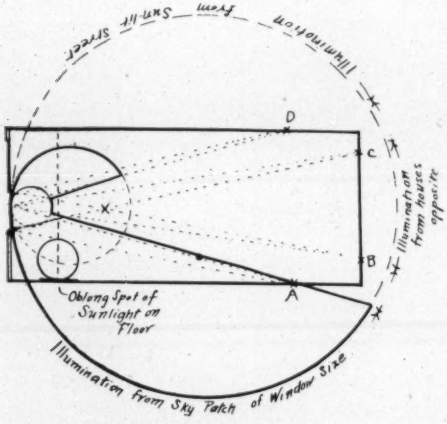
Manner of using daylight spectacles.

or the color matcher, and when used with the appropriate light source they produce daylight for him alone, thus obviating the necessity for a special booth or room in which to do his work. Further advantages of this form of color-matching device are the small amount of special glass needed and the entire freedom from questions of breakage through overheating.

THE COST OF A COMPLETE COPY OF DAYLIGHT.

The question always asked about artificial daylight is: How much does it cost to make a complete copy of daylight illumination in a room? Some figures which I have given elsewhere in connection with a study of the distribution of daylight may, therefore, be of interest here. Pleasant daylighting of the room taken for study, a room 16 feet x 10 feet, was produced when the light of the sky illuminated the whole floor of the room and

FIG. 19.



The distribution of daylight from a window.

when the ceiling was illuminated by the light reflected from the street below, while the opposite houses, which were in shadow, were the only outside objects visible to the occupants of the room. The bright sky, which does most of the lighting of the room, forms a concealed light source. The distribution of light from the window as a light source is shown in elevation in Fig. 19. It was found possible by a construction of mirrors to closely duplicate this distribution and to produce an illumination about one-tenth that of real daylight at an expenditure of about 260 watts. To secure daylight intensity would have taken 2000 watts.

whereas if the light had all been subjected to daylight-producing absorption it should have required 20,000 watts.

If, however, daylight could be produced directly in an illuminant without any waste heat radiation, it would not only be a much more efficient process than that indicated, but even more efficient than any present known artificial light source. Instead of 20,000 watts, 50 watts would suffice.

The ultimate goal of the student of artificial daylight, therefore, is the production of daylight whenever and wherever it is wanted, distributed in any desired manner, at no greater cost than our present yellow artificial light.

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Value of Explosives for Engineering. ANON. (*Amer. Mach.*, xxxix, No. 24, 996.)—The greatest engineering works of the present day are undoubtedly those connected with the removal of vast quantities of soil and rock. The Panama Canal, the Catskill Aqueduct and many other tunnels, excavations and mines are the feats which arouse popular enthusiasm. These would be quite impossible if it were not for the knowledge we have of powerful explosives and modern drilling methods. It is interesting to note that gunpowder as an explosive agent was not used in mines in Europe till a century and a half after the discovery of America, and was first used in Germany. It is only within the last fifty years that mine excavations have been revolutionized by the development of these fundamental requisities, dynamite, the air-compressor, and the power drill.

New Process for Welding Copper. W. SCHIEBER. (*Chem. Zeit.*, xxxviii, 188.)—The two pieces of copper, placed in position, are heated at the proper point by the oxyhydrogen blowpipe until the requisite degree of softening is attained. Complete reduction is then effected in a flame of specially purified hydrogen, and the welding is completed by hammering. It is claimed that the joint is invisible and that the area of juncture is homogeneous in every way with the rest of the metal.

Improving the Properties of Aluminum. A. NEUBURGER. (*Elecktrochem. Zeits.*, xx, 295.)—Alloying with 9 to 12 per cent. of cobalt improves aluminum, but it is still deficient in mechanical strength on account of its coarse crystalline structure. This defect can be overcome by the addition of a small proportion of tungsten or molybdenum, yielding alloys with a tensile strength three times that of pure aluminum. The best results are obtained with: tungsten 0.8 to 1.2 and cobalt 8 to 10 per cent., or molybdenum 0.6 to 1.0 and cobalt 9 to 10 per cent. The forging and rolling qualities diminish and the tensile strength increases with increasing content of tungsten or molybdenum and cobalt. The alloys containing tungsten are somewhat harder than those containing molybdenum.

Excessive Leaf Growth of the Beet. A. VIVIEN. (*Bull. Assoc. Chim. Sucr.*, xxxi, 501.)—Comparative investigations of beets grown on soils treated with (1) abundance of organic nitrogenous manure, (2) little or no manure, showed that in the former case the leaf growth was excessive and the roots contained a lower percentage of sugar. These results do not support the view that the sugar is elaborated only in the leaves.

Metallurgy of Steel-refining in an Acid Electric Furnace. A. MÜLLER. (*Stahl und Eisen.*, xxxiv, 89.)—The most important reaction is the passage of silicon into the steel from the lining and the silica—rich slag. This silicon has a considerable deoxidizing action, and makes it unnecessary to add any deoxidizers. No final desulphurization nor dephosphorization takes place. A certain amount of desulphurization is effected probably by the formation of volatile silicon sulphide at the arc temperature, but this only balances the sulphur contained in the coke, etc. The most suitable slags contain about 15 per cent. CaO, 2 to 5 MgO, 10 to 15 MnO, about 4 FeO, and 55 to 60 per cent. SiO_2. Whilst the working of an acid electric furnace requires care and experience, it is considered that where suitable material is available it has the advantages over the basic furnace, for the production of medium quality steel, of smaller current consumption through a shorter refining period, a saving of deoxidizing additions, cheaper first cost and upkeep of the lining, and cheaper fluxes.

MILD STEEL AND ITS TREATMENT.*

BY

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Member of the Institute.

For the purpose of illustrating metallographic methods and their teaching we may select as a concrete example the treatment of mild steel, a metal so widely used in machine construction, as, for instance, in the manufacture of shafts, and extensively used, also, for a great variety of steel castings. Such steel may contain some 0.30 per cent. carbon and should be of good commercial quality; *i.e.*, should not contain over 0.1 per cent. phosphorus—preferably not more than 0.05 per cent. of that element—nor over 0.05 per cent. sulphur. According to the treatment it has received it may have a tensile strength varying between 60,000 and 100,000 pounds per square inch, while its ductility measured by its elongation may fluctuate between 15 per cent. and 35 per cent. As cast into ingots or other forms this metal shares the shortcomings common to all steel castings,—weakness, lack of ductility, and little resistance to shock. These unwelcome properties of steel in its cast condition are due primarily to the structure of cast steel, which is very coarsely crystalline.

It is well known that the properties of steel may be very greatly improved through properly conducted mechanical and thermal treatment, by which its structure is modified or refined, and it is the purpose of this paper to describe briefly the various structures mild steel may be made to acquire as the result of work and of heat treatment, and to point out the relations existing between each structure and corresponding physical properties, such as hardness, strength, and ductility.

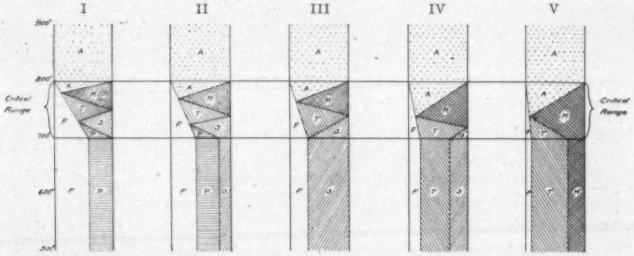
No explanation of the deep structural changes resulting from certain treatments can be given without reference to the thermal critical range of the steel considered. Fortunately, metallography

* Lecture delivered February 6, 1914, before the Mechanical Engineering Society of the Worcester Polytechnic Institute, Worcester, Mass., and communicated by the author.

has so diffused this fundamental knowledge that at the present time there is hardly a metallurgist or metallurgical student ignorant of it. A lengthy description of the occurrence of the critical range of mild steel and of its meaning will not be, therefore, necessary. It will be helpful, however, for the present purpose to illustrate graphically the relations existing between the critical range and the structural changes it is desired to describe.

In Fig. 1 the critical range is represented as covering a temperature zone extending from 700° to 800° C. It will not be necessary, for the aim in view, to take into consideration the existence of two critical points, $A_{3.2.}$ and A_1, within that range, nor the fact that the points on heating, $Ac_{3.2.}$ and Ac_1, occur at

FIG. 1.



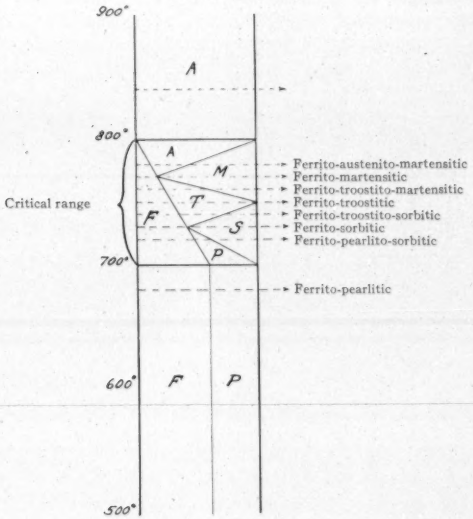
A—Austenite. *M*—Martensite. *T*—Troostite. *S*—Sorbite. *P*—Pearlite. *F*—Ferrite.

temperatures some 25 to 50 degrees higher than the corresponding points on cooling, $Ar_{3.2.}$ and Ar_1.

Above its critical range the steel we are studying consists, like all steels, of a solid solution of iron and carbon. In this condition the two constituents are so completely merged that their independent existence cannot be recognized by any physical means; they form a chemically and physically homogeneous mass. Whether carbon in its elemental condition is dissolved in the iron, or whether it is the carbide of iron, Fe_3C, which the iron holds in solution, is here immaterial. We may likewise ignore the various allotropic conditions assumed by iron. The solid solution of iron and carbon stable above the critical range is called "austenite." Whenever it is possible to preserve austenite in the cold to the exclusion of other constituents and to

microscopically examine its structure, it is found to be made up of crystalline polyhedra or grains exhibiting in a polished section the appearance of a network, the meshes representing sections through as many grains, and the net itself, junction lines between adjacent grains (see Fig. 3). The size of the austenite grains increases with (1) the maximum temperature from which cooling starts, (2) the length of time during which the metal was kept at that temperature, and (3) the slowness

FIG. 2.

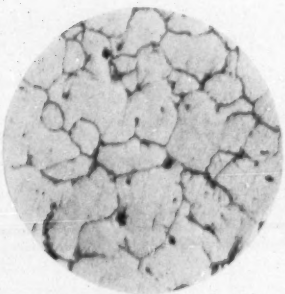


of its cooling to the critical range. It will not be necessary, nor is it desirable, to further discuss here the probable crystallography of austenite. As to its physical properties, austenite is hard, tenacious, and ductile, but has a low elastic limit.

On slow cooling through the critical range, as shown in Fig. 1, Diagram I, the solid solution of iron and carbon is converted into a mechanical mixture or aggregate of ferrite and pearlite, the latter constituent itself being an aggregate, in definite proportion,

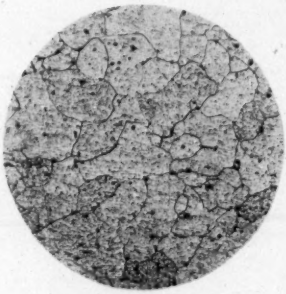
of "ferrite" and the carbide Fe_3C, or "cementite." Ferrite and pearlite may be considered as representing the proximate structural composition of the steel, while ferrite and cementite are its ultimate structural constituents. The structures of ferrite and pearlite are shown respectively in Figs. 4 and 5. It will be noticed that ferrite, like austenite, and, for that matter, like pure metals and solid solutions in general, is made up of polyhedric crystalline grains, giving rise, on sectional polishing, to network structures. Pearlite is built up after the pattern so characteristic of eutectic and eutectoid alloys, of parallel, alternate plates of its two components, namely, ferrite and cementite. These plates are so thin, however, that a magnification exceeding 200 diame-

FIG. 3.



Austenite. (Magnified 100 diameters.)

FIG. 4.



Ferrite. (Magnified 100 diameters.)

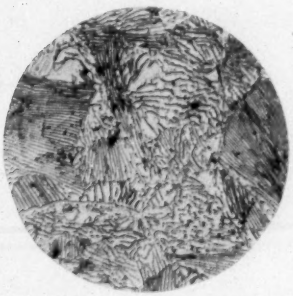
ters is generally required for their resolution. Ferrite is very soft and very ductile, but relatively weak, while pearlite is very tenacious and much harder, but also much less ductile.

It is seen that in cooling through its critical range steel undergoes deep structural changes, being converted from the state of a solid solution to that of an aggregate of varying coarseness. So great a transformation must be accompanied by no less momentous alteration of properties, and, indeed, there is little in common between the physical properties of austenite and those pertaining to the ferrito-pearlitic structure existing below the critical range.

Steel with 0.30 per cent. carbon is composed, after slow

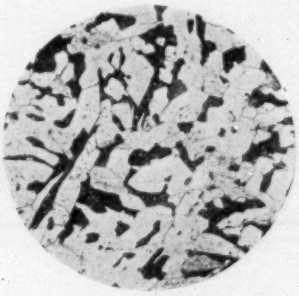
cooling through its critical range, of 64 per cent. ferrite and 36 per cent. pearlite, as graphically shown in Fig. 1, Diagram I. Its structure is illustrated in Fig. 6. Bearing in mind the physical properties of its two components, ferrite and pearlite, it will be obvious that mild steel in its ferrito-pearlitic condition, while more tenacious and less ductile than ferrite, will be considerably less tenacious and more ductile than pearlite. Its tenacity, as a matter of fact, should be in the vicinity of 70,000 pounds per square inch, and its elongation in 2 inches should be about 20 per cent. These properties, moreover, will vary considerably in accordance with the coarseness or fineness of the ferrito-pearlitic structure, the finer structure being generally the

FIG. 5.



Pearlite. (Magnified 500 diameters.)

FIG. 6.



Mild steel (0.30% C.). Ferrito-pearlitic structure. (Magnified 100 diameters.)

more ductile. The structure of the steel, after slow cooling through the critical range, will, as a rule, be the coarser, the coarser the austenite immediately before its transformation, and this in turn, as already noted, depends chiefly upon the maximum temperature from which cooling started, the time the metal was kept at that temperature, and the rate of cooling.

It should be borne in mind that the ferrito-pearlitic structure just mentioned, and which corresponds to the end products of the structural transformation taking place within the critical range, results from *slow* cooling through that range, as, for instance, in allowing the piece to cool within the furnace in which it was heated. On hastening the cooling, structural conditions may be

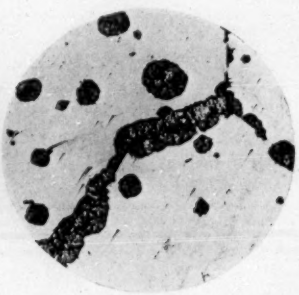
produced corresponding to widely different properties, as will now be described.

The transformation of the austenitic solution into a ferrito-pearlitic aggregation is not sudden, but, on the contrary, covers a notable range of temperature, while transition constituents are formed within the critical range, as depicted in Figs. 1 and 2. It is intended to show, by means of these diagrams, that, on entering the critical range, the austenite existing above that range is *gradually* converted into "martensite" with rejection of ferrite, a rejection which continues all through the range; that the martensite, on further cooling, is, in turn, transformed into troostite, which, at a still lower temperature, is itself converted into sorbite;

FIG. 7.

Martensite. (Magnified 100 diameters.)

FIG. 8.



Troostite and martensite. (Magnified 100 diameters.)

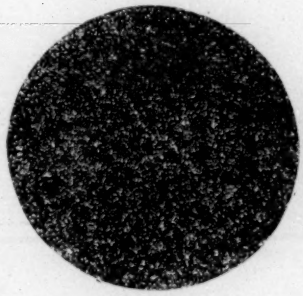
while, finally, pearlite, the end product, forms as the steel emerges from its range. We thus recognize the existence of three so-called transition constituents,—martensite, troostite, and sorbite,—but it will be unnecessary to enter here into a discussion of their probable nature, a subject which is still, to a certain extent, a controversial matter. The structure of these constituents is illustrated in Figs. 7, 8, and 9. Martensite appears to be made up of needles, often forming equilateral triangles; troostite, which in Fig. 8 is seen associated with martensite, consists of irregular ragged or rounded masses; while sorbite exhibits a finely granular and rather indistinct structure. In regard to physical properties, martensite is very hard and brittle, troostite

less hard and less brittle than martensite, while sorbite is less hard than troostite and more tenacious, but less ductile than pearlite.

By referring to Fig. 2 it will be seen that, theoretically at least, seven different structural conditions may be conceived to exist momentarily as the steel undergoes its critical transformation; namely, ferrito-austenito-martensitic, ferrito-martensitic, ferrito-troostito-martensitic, ferrito-troostitic, ferrito-troostito-sorbitic, ferrito-sorbitic, and ferrito-pearlito-sorbitic.

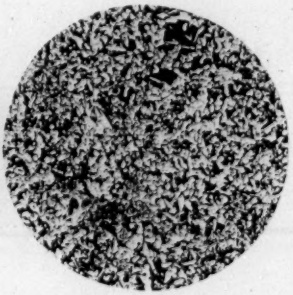
The mechanism of the structural changes depicted in Fig. 1, Diagram I, and in Fig. 2, refer to the changes taking place when

FIG. 9.



Sorbite. (Magnified 100 diameters.)

FIG. 10.

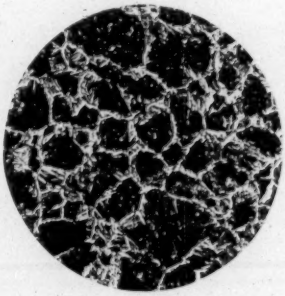


Mild steel (0.30% C.). Ferrito-sorbitic structure. (Magnified 100 diameters.)

the cooling is slow enough to permit a complete transformation of the metal with final production of a ferrito-pearlitic structure. It will now be shown that through properly regulated cooling the transformation may be arrested at any desired stage in accordance with the physical properties wanted, which may vary from the hardness and brittleness of the quenched metal to the great softness and ductility resulting from very slow cooling. Between these two extreme types lies a great variety of combinations of hardness, strength, and ductility, each set corresponding to a well-defined treatment; hence the science and art of the heat treatment of steel, the importance of which steel makers and users are only now beginning to fully appreciate.

In Fig. 1, Diagram II, the cooling has been so hastened that on reaching the bottom of the critical range the sorbite had been but partially converted into pearlite, the necessary time for its complete transformation having been denied. This quicker cooling has also prevented a full separation of the ferrite, as indicated in the diagram. The resulting structure may be described as ferrito-sorbito-pearlitic. Large pieces cooled in air often acquire it. Obviously, because of the properties of sorbite, steel in this condition is more tenacious, but less ductile, than the same metal in its ferrito-sorbitic state.

FIG. 11.



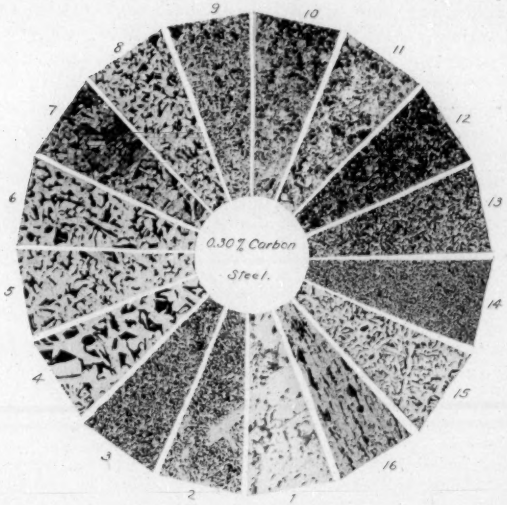
Mild steel (0.20% C.). Ferrito-sorbito-troostitic structure. (Magnified 100 diameters.)

In Fig. 1, Diagram III, is represented the mechanism by which we can conceive the production of sorbite to the exclusion of pearlite, owing to relatively rapid cooling in passing through the critical range. The steel is now ferrito-sorbitic, while the amount of ferrite it contains is but half the amount of that constituent present in the ferrito-pearlitic metal (Fig. 1, Diagram I), the necessary time for its complete separation having been denied. In its ferrito-sorbitic condition the steel is decidedly more tenacious, but less ductile, than when ferrito-pearlitic. It is also harder, has a higher elastic limit, and is in a better condition to resist shocks and alternate stresses. A ferrito-sorbitic structure is readily produced in allowing small pieces to cool in air, or

larger ones in oil.[1] Fig. 10 shows the structure of mild steel when ferrito-sorbitic.

In Fig. 1, Diagram IV, the cooling has been so rapid that, on emerging from its critical range, the metal is caught in a

FIG. 12.



Various structures of mild steel (0.30% C.).

1. Steel as cast.
2. Steel cast and imperfectly annealed (remnants of ingotism).
3. Steel cast and properly annealed.
4–8. Heated to various temperatures above critical range for various lengths of time and slowly cooled in furnace. Ferrito-pearlitic structures of different degrees of coarseness.
9–13. Heated above critical range, followed by cooling in air or oil, or heated above critical range, cooled in water or oil and reheated to 600° C. Ferrito-sorbitic or ferrito-sorbito-troostitic structures.
14. Forged and finished at low temperatures.
15. Forged and finished at high temperatures.
16. Cold worked.

ferrito-troostito-sorbitic state, only a small amount of ferrite, moreover, being present. The metal is now harder and has lost

[1] It may also be obtained by quenching the metal from above its critical range in water or oil, thereby securing a fine structure, followed by reheating to some 600° C. to cause the transformation into fine sorbite of any existing troostite or martensite.

much of its ductility because of the presence of troostite. This structure may be produced by quenching small pieces in oil, or larger ones in water, or by a suitable tempering of hardened pieces. The structure of mild steel containing ferrite, troostite, and sorbite is shown in Fig. 11.

In Fig. 1, Diagram V, the steel has been cooled so quickly that some martensite, as well as troostite, remains undecomposed on reaching the bottom of the critical range, while but a very small amount of ferrite has had time to separate. In this ferrito-troostito-martensitic condition the metal is hard and deficient in ductility. A structure of this type may be produced by quenching small pieces in water.

The retention of martensite to the exclusion of troostite, and, *a fortiori*, the retention of austenite, is quite impossible in mild steel. While martensitic structures, moreover, are those needed in high carbon steel for the production of cutting tools, for instance, they are never wanted in low carbon steel, the structures depicted in Fig. 1, Diagrams I, II, and III, being the only ones of interest to the users of such steel.

Fig. 12 is a composite photo-micrograph showing the various types of structure mild steel may be made to acquire. The legend makes it self-explanatory.

The Colloidal Nature of Caoutchouc. A. WAGNER. (*Chem. Zeit.*, xxxvi, 833.)—Ahrens's statement that the so-called Para-spots in pure vulcanized mixtures consist of an organic substance and not of crystallized sulphur is shown to be erroneous by the following experiment. When a thin section of pure vulcanized rubber is placed together with a solvent, such as benzol, between two glasses and examined under a microscope of comparatively low magnification, ramified, arborescent forms are seen, which are composed of small crystals; there are also present small, round, floating bodies, which prove to be amorphous sulphur. After a short time this sulphur dissolves, and the spherical bodies as well as the arborescent forms gradually disappear; with carbon bisulphide as a solvent, solution is more rapid. This solution is clear except small fragments of foreign matter (filling, etc.). Thus the theory of the network structure of albuminoid compounds or of polymerized or oxidized rubber in vulcanized rubber appears untenable. Further proof of this is given by the fact that when vulcanized rubber containing no free sulphur is examined as above, the structure described is not visible—at any rate, not under such low magnification as is necessary for the identification of the different crystalline forms of free sulphur in rubber.

COAL AND ITS BY-PRODUCTS.*

BY

LOUIS CLEVELAND JONES, Ph.D.,

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THERE have been listed and described perhaps several hundred thousand organic compounds, practically all of which can be obtained directly or indirectly from the decomposition of coal by heat.

Carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, and the halogens are normal constituents of ordinary coal, so that all compounds containing any or all of these substances, in any proportion, are possible direct by-products of coal. Coal also at times contains unusual constituents such as the rare elements in the ash, even gold and radium. We have known a coal ash to contain so much gold that the possibility was considered of treating its ash after burning, as a gold ore. There are seams of coal in southern Indiana and eastern Kentucky which contain iron ore. The ash of some coals in eastern Pennsylvania and eastern Kentucky makes an excellent high grade refractory fire-clay. One of the principal coal seams in Illinois consists of an upper bench of limestone.

But the true by-products of coal are the organic products, and they are so numerous that it would weary you to mention even all their group names. Acid bases, alkaloids, alcohols, gums, varnishes, solvents, sugars, saccharine, and stuffs as bitter as saccharine is sweet; disinfectants, dye stuffs of brilliant hues, stimulating or sleep-producing drugs, healing medicines and violent poisons, vile odors and pleasing perfumes, are all by-products from the carbonization of coal.

But I must not weary you with the recital of these products and their nature, for I wish to consider the nature of coal itself.

In order more clearly to understand what coal is, we must look into its origin.

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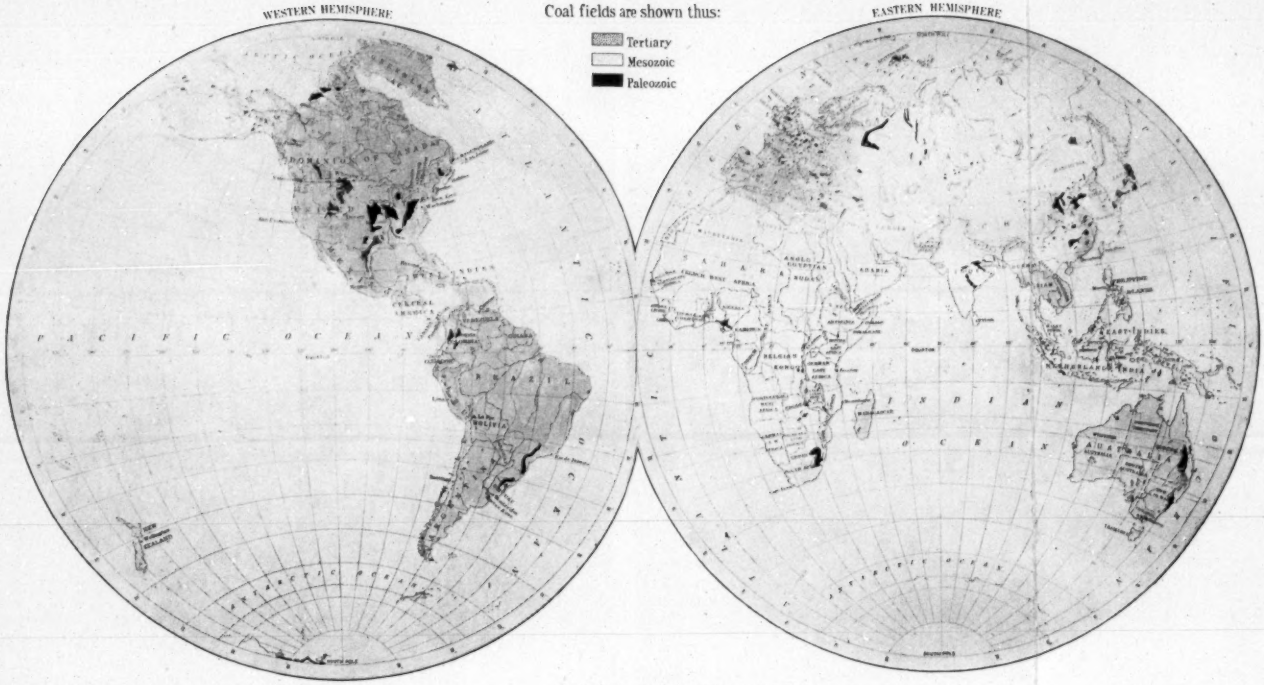
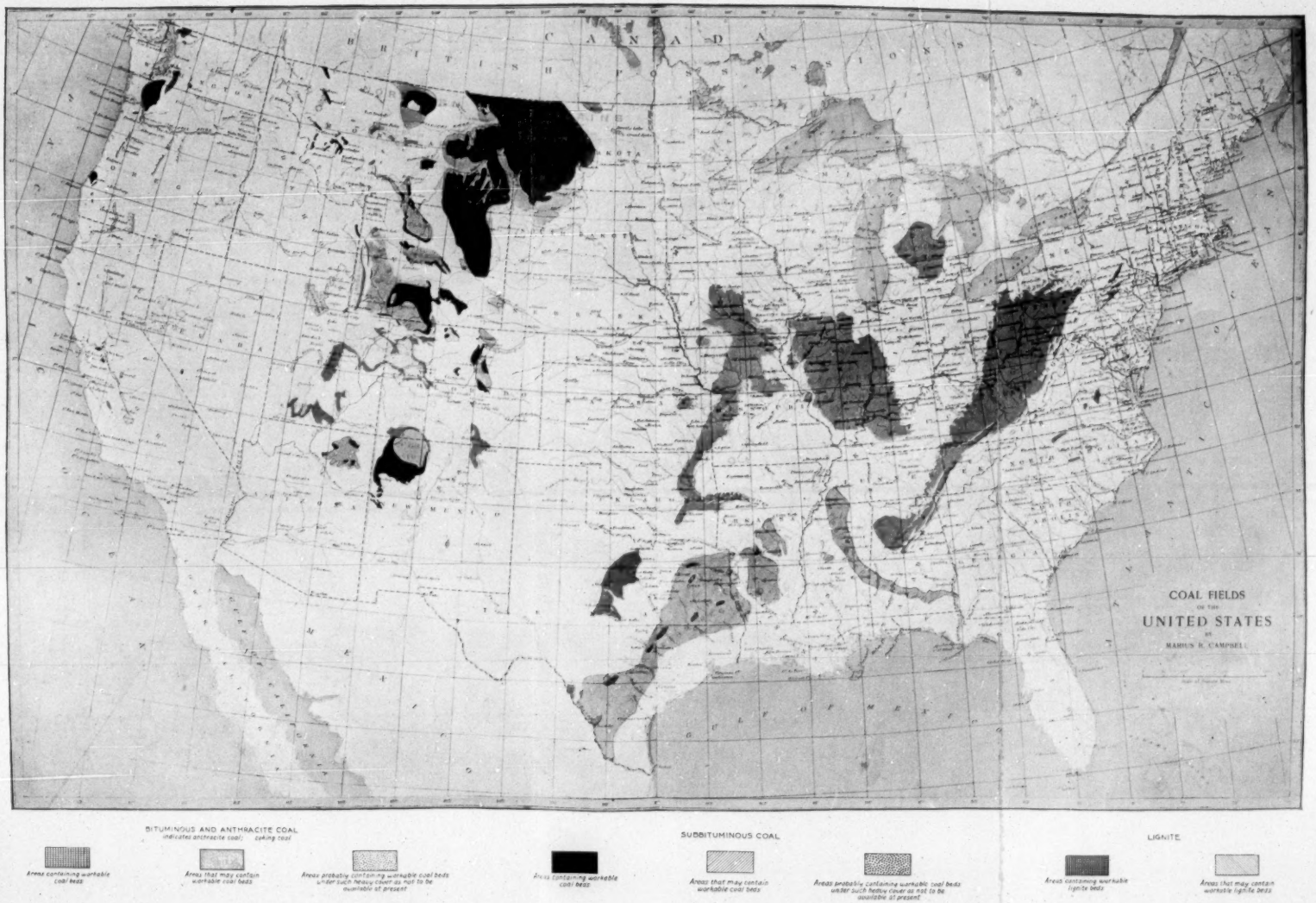
* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, March 5, 1914.



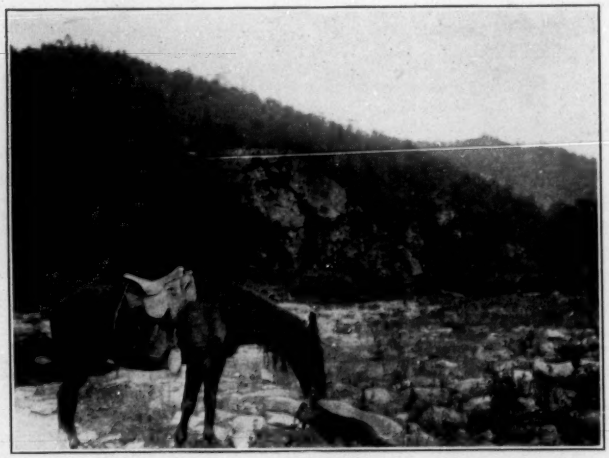
Coal fields of the world.


C A N A D A
B R I T I S H P O S S E S S I O N S
COAL FIELDS
OF THE
UNITED STATES
BY
MARIUS R. CAMPBELL
BITUMINOUS AND ANTHRACITE COAL
indicates anthracite coal; coking coal
Areas containing workable coal beds
Areas that may contain workable coal beds
Areas probably containing workable coal beds under such heavy cover as not to be available at present
SUBBITUMINOUS COAL
Areas containing workable coal beds
Areas that may contain workable coal beds
Areas probably containing workable coal beds under such heavy cover as not to be available at present
LIGNITE
Areas containing workable lignite beds
Areas that may contain workable lignite beds

EARLY ATMOSPHERE OF THE EARTH.

A generation ago it was not good science to talk much about transmutation. However, after the recent accomplishments of Madam Currie, Sir William Crooks, Professor Rutherford, and others, transmutation has been brought again into the realm of science.

FIG. 1.



Railroad tunnel piercing nearly vertical layer of Lee conglomerate near Big Stone Gap, Virginia.

After the primordial substance had been transmuted into some eighty present well-known elements, and these were still in the condition of vapor uncondensed, there was present, fortunately, sufficient oxygen to combine with all the other elements which cared to associate with it, and just a little more. These vapors cooled and condensed to a molten mass in the form of a sphere—our earth. 45 per cent. of the earth's crust, say one-quarter of the whole weight of this sphere—the earth—is represented by the oxygen which has combined with other elements to form rocks and water. One-quarter of the weight of the earth

represents 32 billion trillion tons of oxygen, and there was left over uncombined in our atmosphere 670 trillion tons, or only two-millionths of one per cent. of the total. So you see that it is by a rather close margin that we now have enough oxygen in our air to enable human beings to live.

The earth, now cooled to the condition of a fairly homogeneous fused mass of rocks, may be compared with a tank of

FIG. 2.

Typical scene in Letcher County, Kentucky, showing log cabin and path leading to coal opening in the mountain side.

fluid melted glass, composed of impure mixed silicates with an excess of silica, about 75 per cent. of the total weight of the earth's crust, while the mixture in an ordinary glass furnace contains also about the same percentage (70 to 75 per cent.) of silica.

Above this fused mass was an atmosphere containing the present amount of air (nitrogen and oxygen), and also as steam all the water now condensed in the ocean, and all the carbon dioxide now fixed in the form of limestone (calcium carbonate).

There was also present, of course, in that atmosphere relatively small amounts of sulphur and halogens, since deposited as salts.

A rough estimate indicates that the total amount of water now in the world, if evenly distributed, would cover all the earth's surface 10,000 feet deep (say 3000 M.).[1] Likewise the limestone deposits of the earth's surface are, on an average, 6000 feet (say 1800 M.) deep.

On this basis, then, and since one atmosphere equals 10 tons per M^2 of surface, we can readily calculate that, with all the water as vapor, and all the carbon dioxide as gas in the atmosphere, the pressure upon the earth's surface would be enormous, *i.e.*:

± 300 atmospheres water vapor.
200 atmospheres carbon dioxide.
1 atmosphere nitrogen and oxygen.

Thus the earth's atmosphere was composed, by volume, of

	Per cent.
Steam	79.2
Carbon dioxide gas	20.4
Air (oxygen and nitrogen)	.35

all under a pressure of say 500 atmospheres or 7350 pounds per square inch. Under these conditions cooling was rapid, due to the continuous condensation of water vapor high in the atmosphere, and its re-evaporation lower down.

When the earth's crust became sufficiently cool the solid granite masses, thrust up by contraction, were violently attacked by this superheated steam and carbon dioxide under tremendous pressure. Decomposition of the granite was rapid, with formation of shales (aluminum silicates) and bases (alkalies and alkaline earths) from feldspars, and sandstones (silica) from quartz. Cooling continued below the boiling-point of water so that most of the water condensed, leaving a moist atmosphere containing principally CO_2, *i.e.*, over 98 per cent. of CO_2, and less than 2 per cent. of nitrogen and oxygen together.

In these warm waters shales and sandstones were sedimented,

[1] Calculated from average depth of oceans as determined by measured speed of volcanic tidal waves crossing the Pacific.

and at the same time lime from the decomposed granites was carbonated or bicarbonated and deposited to form the enormous limestone beds of the geologic ages preceding the coal-forming era.

Since our limestone deposits are generally sedimentary it is evident that much water had condensed before the great bulk of the carbon dioxide was taken from the air by the decomposing granites. At any rate, in this manner, at the same time water was condensed, or subsequently, the formation of limestone (possibly, as Dana says, by means of animal or vegetable organisms), with absorption of carbon dioxide, continued until, with decreased temperature and decreased amounts of carbon dioxide in the air, plant and animal life became possible. Experiments indicate that plants of our time will not thrive in an atmosphere containing more than 10 per cent. of carbon dioxide, but that they do benefit considerably by percentages higher than normally present in our air. Certainly in the carboniferous era plant life flourished as never before or since, due to a warm, moist climate, and probably also to high atmospheric pressure, and particularly in the presence of a moderately high percentage of carbon dioxide. Possibly also the highly carbonated earth waters, as recent experiments suggest, stimulated a luxuriant growth of vegetation.

AMOUNT OF CARBON DIOXIDE IN THE ATMOSPHERE IN COAL ERA.

The ratio of the thickness of limestone beds deposited before the beginning of the coal-forming era, to the limestone formed from granite decomposed since, would permit us to calculate what amount of the 98 per cent. of carbon dioxide originally present remained in the atmosphere when our coal beds were formed. Such estimates are extremely indefinite, but it is quite probable that the atmosphere of the coal-forming era contained from 2 to 5 per cent. of carbon dioxide, while at present, as we know, we have but .03 of one per cent. Furthermore, this carbon dioxide and high moisture content of the air doubtless brought about a more uniform distribution of heat, so that at any rate tropic vegetation flourished from the equator to the poles.

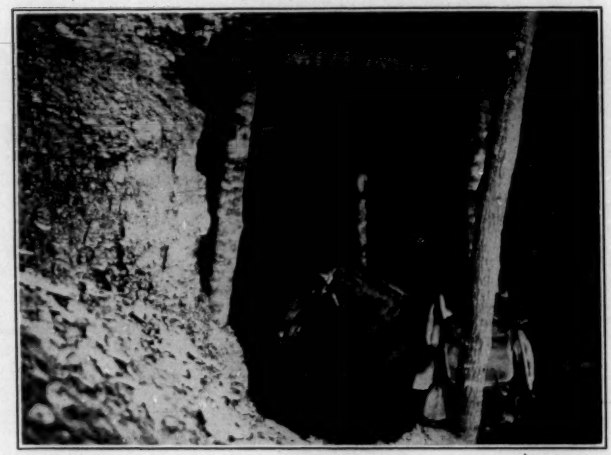
In addition to the absorption of carbon dioxide during and

since carboniferous times to form limestones, the great coal deposits of the world have taken their carbon equivalent from the carbon dioxide of the atmosphere.

CO_2 REQUIRED TO FORM COAL.

A committee of the XII International Geological Congress, held in Canada last fall, determined the total mineable coal de-

FIG. 3.



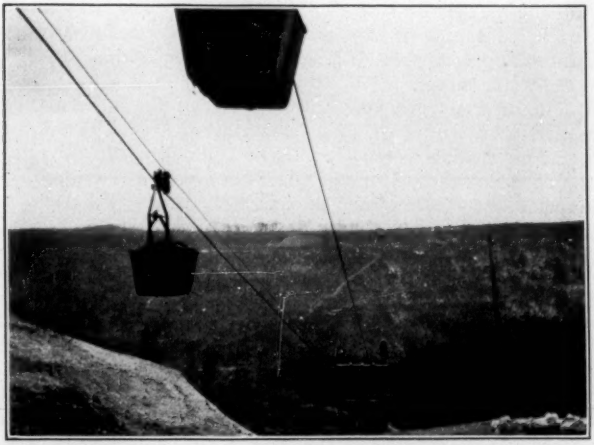
The thickest opening in Elkhorn Seam, Letcher County, eastern Kentucky. The horse is standing on a level with the bottom of the coal seam.

posits of the world to be at most 7400 billion tons. Double this, or 14,800 billion tons, may be taken to safely represent all other coal in thin seams beneath the ocean and in other ways not mineable.

Now, if we compare our total coal deposits, 15,000 billion tons (calculated into its equivalent of carbon) with the .03 per cent. of carbon dioxide still in our atmosphere (equivalent to 700 billion tons of carbon), we get the striking information that the coal deposits of the world required and took from the

air 11,000 billion tons of carbon for their production, and there are left in the air to-day but 700 billion tons of carbon, or but 6 per cent. of the total originally required to produce the coal we have. In other words, no more coal could have been deposited because the raw material was practically used up. This world cannot, therefore, have another carboniferous era until we burn up our present deposits, and when we do get them

FIG. 4.



Bucket cable line bringing coal across a valley in eastern Pennsylvania.

burned up there will be say .6 per cent. more CO_2 in the atmosphere, and the same amount less of oxygen than at present.[2]

FLUCTUATIONS OF CARBON DIOXIDE IN THE ATMOSPHERE.

How much carbon dioxide has been absorbed by granites decomposed since the beginning of the carboniferous age is not readily determined, but the larger amount present at that time,

[2] Sir William Herschel calculated the total weight of the earth's atmosphere as 11⅔ billion tons. It is really 11⅔ quintillion pounds or 5,800 trillion tons, five hundred times Sir William's figure.

besides directly giving richer food to plant life, has been considered sufficient to so modify climate as to account for the tropical conditions prevalent at that time.

Arrhenius and Chamberlain have attempted to explain the known fluctuations of climate as indicated by glaciation by corresponding fluctuations in the carbon dioxide of the atmosphere. But a sufficient cause for such changes in the amount of carbon dioxide is hard to find. We may estimate the earth's water to contain perhaps seven parts carbon dioxide per one hundred thousand, in the form of bicarbonates, more than sufficient if transferred to the atmosphere to supply carbon for another coal-forming epoch, but boiling would be required to drive it into the atmosphere.

The decomposition of a small portion of the limestone, by heat or otherwise, would, of course, return the requisite amount of carbon dioxide to the air to give again to earth universal tropical conditions. Without heat, however, any acid would be required to evolve carbon dioxide, but no such acid suggests itself other than a rather improbable one, *i.e.*, nitric acid formed by oxidation of nitrogen by electrical discharges which the earth in its history may have developed or encountered.

AMOUNT OF CARBON DIOXIDE NOW IN ATMOSPHERE CONSTANT.

It would not be unreasonable to estimate that the ordinary growth of vegetation and forestry may consume 400 grams of carbon dioxide per square meter of surface per year, or 100 grams per square meter over the entire surface of the earth, or about 2 per cent. of the 4400 grams of CO_2 in our present atmosphere. The production of carbon dioxide by the 1200 million tons coal annually consumed is but one-seven-hundreth part of the carbon dioxide already in the air. At any rate the present increase or decrease of the carbon dioxide in the air is not perceptible by present means of analysis. Any further decomposition of granities, though now slow, due to the comparative small amount of the rock exposed, must absorb a corresponding amount of carbon dioxide from the air, and when the minutest amount more has been absorbed, compared with what has already been accomplished by such decomposed granite, no more carbon dioxide will remain to sustain plant life and the earth will become a dead world. But granites, besides being

protected (covered up) from weathering, are also decomposing more slowly because of the comparatively low temperature and low pressure of the atmosphere acting upon them. Since observations have been made, no diminution of the carbon dioxide in the atmosphere has been observed.

MINEABLE COAL RESOURCES OF THE WORLD.

In the following table are given the coal resources of the world, and on this basis it will not be difficult to predict great commercial growth in such nations as China, when once she has had a generation of technical education.

The present production, however, of coal in China, as given for 1910, is only a little over one-half that of Belgium.

COAL RESOURCES OF THE NATIONS OF THE WORLD. (In million tons.)

[From data in report of committee of XII International Congress of Geology, Canada, 1913.]

Nation.	Anthracite.	Bituminous.	Sub-bituminous.	Total.
United States	19,684	1,955,521	1,863,452	3,838,657
North America (except United States)	2,158	284,162	948,454	1,234,774
China	387,464	607,523	600	995,587
Germany	.....	409,975	13,381	423,356
Asia (except China)	20,173	152,575	111,251	283,999
Great Britain and Ireland	11,357	178,176	.....	189,533
Oceania	659	133,481	36,270	170,410
Europe (except Germany, France and Great Britain and Ireland	39,718	92,331	21,669	153,718
Africa	11,662	45,123	1,054	57,839
South America	700	31,397	.....	32,097
Total	496,846	3,902,944	2,997,763	7,397,553

(Note enormous deposits of anthracite in China.)

From the following table showing the annual coal production of the principal countries of the world, and the table calculated from it showing the percentage increase in production by five-year periods, we are able to predict with some degree of certainty a comparatively early exhaustion of the coal resources of the world. The incomplete data for the years succeeding 1910

TABLE OF THE ANNUAL COAL PRODUCTION OF PRINCIPAL COUNTRIES OF THE WORLD. (In million tons.)

[From Report of XII International Geological Congress, 1913.]

Country.	1865.	1870.	1875.	1880.	1885.	1890.	1895.	1900.	1905.	1910.
Australia	.....	.....	.....	.....	.....	.....	4.01	6.48	6.83	10.00
New Zealand	.....	.....	.....	.....	.....	.....	0.76	1.11	1.41	2.23
China	.....	.....	.....	.....	.....	.....	.....	.....	.....	14.59
India	.....	.....	.....	.....	.....	.....	2.65	6.22	7.92	12.09
Japan	.....	.....	.....	.....	.....	.....	4.84	7.43	11.89	14.79
South Africa	.....	.....	.....	.....	.....	.....	1.40	0.76	3.22	5.50
Canada	.....	.....	.....	.....	.....	.....	3.19	5.09	7.96	13.01
United States	24.79	29.95	48.20	66.83	102.18	141.62	177.59	243.41	351.12	445.81
Mexico	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.45
Great Britain	99.76	112.24	135.49	149.38	161.96	184.59	194.35	228.77	239.89	264.50
Spain	0.45	0.66	0.61	0.85	0.94	1.18	1.77	2.58	3.20	3.55
France	11.84	13.30	16.95	19.36	19.51	26.08	28.24	33.40	36.05	38.57
Belgium	11.84	13.69	15.01	16.88	17.44	20.37	20.41	23.46	21.84	23.13
Germany	28.33	34.88	48.53	59.12	73.67	89.29	103.96	149.79	173.66	221.98
Austro-Hungary	2.03	8.36	13.06	14.80	20.43	26.10	27.25	39.03	40.72	38.00
Italy	.....	.....	.....	.....	.....	.....	0.25	0.48	0.31	0.40
Sweden	.....	.....	.....	.....	.....	.....	0.20	0.25	0.33	0.21
Russia	0.33	0.69	1.17	3.27	4.24	7.00	9.10	14.76	17.12	24.57
Other countries	2.71	4.04	6.26	9.28	12.45	16.89	1.75	2.90	4.55	8.00
Total	182.08	217.81	285.30	339.37	412.82	513.12	581.72	765.92	928.02	1,143.38

show no falling off in this production of coal, but, in fact, it is already evident that the normal five-year increase will be exceeded by 1915.

INCREASE IN COAL PRODUCTION BY FIVE-YEAR PERIODS FROM 1865 TO 1910.

Percentage increase over previous period.

	1865 to 1870.	1870 to 1875.	1875 to 1880.	1880 to 1885.	1885 to 1890.	1890 to 1895.	1895 to 1900.	1900 to 1905.	1905 to 1910.	Average.
United States	21	61	38.5	53.0	38.0	26.0	37.0	44.0	27.0	38.4
World	19	14	19.0	21.5	24.3	13.3	31.6	21.3	23.3	20.8

Thus coal production of the world doubles every 20 years and of the United States doubles every 11 years.

On this basis the world's resources will last 250 years, while the United States at her higher increase in production would exhaust her own enormous supply in 110 years.

Furthermore, if we purchase coal lands now in the United States at present values, say 2 cents per ton in the ground, and charge against this investment compound interest at 6 per cent., such unused coal as we may have unmined at the end of 120 years will have cost us $20 per ton, or say f.o.b. cars $21, the same figure that White & Hazard paid for coal 100 years ago. Two cent coal carried under the same conditions 250 years would cost about $40,000 per ton. So we see that it is practically immaterial to our posterity whether any coal lasts 250 years or not. Its price would be prohibitive, but of course prohibitive prices can never be maintained.

COALS ARE RESIDUES OF CARBONIFEROUS VEGETATION.

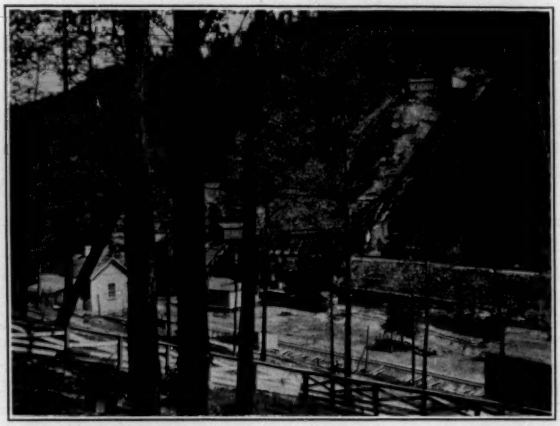
Now, we have 7400 billion tons mineable coal, but of greatly different varieties. And though capable of producing an enormous number of by-products, the substance of the different coals is not so mysterious if we remember that each variety of coal represents only a different step in nature's slow process of converting the vegetation of the carboniferous era into the fuels so necessary to our modern civilization.

Essentially, therefore, coal was originally wood (cellulose $(C_6H_{10}O_5)_n$ and resins, now converted in the age long processes

of nature into peat, lignite, semi-bituminous, bituminous, gas coal, smokeless coal, semi-anthracite, anthracite, graphite, diamond, and we might also place carbon dioxide, the raw material from which wood is made, at the head of the series.

It is thus quite remarkable that our fuel coals, near the end of the series, upon burning return again to the air as carbon dioxide, to be converted by photo-chemical processes a second time into vegetation (wood), and thus repeat the cycle of the

FIG. 5.



Typical drift mine in Tug River district, West Virginia.

carboniferous age. But geological ages are made up of cycles of incomprehensible lengths of time. So here when we seek the origin of graphite which is found in the granites of the archaic ages, we can only answer, a previous carboniferous era.

This series of products, with the geological and paleobotanical evidences of its succession, is so reasonable that there can be little doubt that it accurately represents ancient vegetation in the different stages of carbonization in nature's by-product retort.

The earth's crust is such a retort, and the by-products have

been saved in the form of asphalt, bitumen, petroleum and natural gas.

We may estimate that over 70 per cent. of the weight of wood is lost in being converted to coal, and, according to tests given below, possibly one-half of this loss was carbon dioxide and the other half combustible gas and oils. This oil and gas, nature's by-products, stored beneath folds of rock strata, constitute our present sources of petroleum and natural gas.

NATURAL BY-PRODUCTS OF CARBONIZING ANCIENT VEGETATION RESIDUES.

Since commercial carbonizing of coal gives the benzene series of products, and not paraffines as existing in petroleum and natural gas, efforts have been made to explain the origin of natural gas and petroleum from animal remains, and Moissan has suggested the carbide theory. We believe, however, that the slow distillation of coal at low temperatures is a more logical explanation.[3]

Industrial experiments recently carried on in England upon low temperature distillation by the Coalite process, and more recently on coking coals at even lower temperatures, and *in vacuo*,[4] indicate that petroleum products identical with those found in nature are thus obtained.

In duplicating nature's conversion of bituminous coals to anthracite, the modern by-product oven, operating at a temperature of 1000° C. or more, does the work of ages in a day, producing coke the equivalent of natural anthracite, and, in place of natural gas and petroleum, illuminating gas and oils of the benzene series.

In the electric furnace we convert coke into graphite and Moissan has converted graphite dissolved in cast iron into the diamond, the end of the series. But at these high temperatures, as stated before, the by-products are largely of the benzene series, while nature's by-products are of the methane series.

[3] Mabery's study of "Mahone Petroleum, its Recent Origin and the Origin of Petroleum in General," has just come to my attention. The evidence given leaves little doubt that petroleum is one of nature's by-products of coal.—J. I. and Eng. Chem., Feb. 14, p. 101.

[4] Pictet & Bouvier, Ber., 1913, p. 3342.

LOW TEMPERATURE CARBONIZING EXPERIMENTS.

Recently, therefore, in our laboratory at Syracuse, we have tried to determine the nature of the products at low temperatures, starting with the wood and going through the series to coke.

Our experiments are still incomplete, but some of the results are tabulated below. For example, wood, brown lignite, black lignite, Illinois coal, Kanawha gas coal, smokeless coal and anthracite were gradually heated until decomposition started and a small part of the gas was driven off. The results are calculated to the pure, dry coal basis.

In these experiments we used a cast-iron bomb, heated electrically or in a muffle furnace. This bomb, with absorbing apparatus and gas holder, was devised by the writer about eight years ago, and has been much used in the laboratories of the U. S. Government, and in our laboratories, for determining the nature and amount of products from various coking coals under varying conditions.

	Wood.	Brown lignite.	Black lignite.	Illinois coal.	Kanawha gas.	Smokeless.	Anthracite.
Analyses (%):							
H_2O and volatile	75	70.5	65.6	42.0	29.0	20.0	7.9
Fixed carbon	25	29.5	35.0	58.0	71.0	80.0	92.1
Temp. decomposition (° C.)	150	230	260	300	330	330	340?
Temp. range of expts. (° C.).....	150–188	230–320	260–340	300–330	300–360	330–400	230–475
Litres gas evolved from 500 gms....	43.5	10.8	14.0	11.5	14.0	9.3	4.6
Cu. ft. gas per ton..	3080	750	1000	815	1000	659	326
Gas analysis (%):							
CO_2.....	58.6	55.6	49.3	24.1	7.3	6.5	10.3
C_6H_6.....	.5	.6	.9	2.8	.5	2.6	1.3
C_2H_4.....	.6	1.0	.8	2.2	1.4	2.3	.4
CO.....	35.0	24.7	19.5	10.6	6.0	4.1	2.6
CH_4.....	1.3	11.4	19.5	43.3	57.4	53.5	70.6
H_2.....	1.0	.3	.0	3.4	14.6	9.7	.0
N_2.....	3.0	6.4	10.0	13.6	12.8	21.3	14.8
Per cent. by weight volatilized.....	51.9	26.8	31.0	23.7	12.2	10.0	.7
Analysis of residue:							
Volatile.....	56.0	39.0	30.8	23.3	18.7	13.9	7.1
Fixed carbon....	44.0	61.0	69.2	76.7	81.3	86.1	92.9

The residue from the first carbonizing test on the brown lignite was again heated from 450 to 500° C., producing 3500 cubic feet per ton of gas of analysis as shown under heading "A."

This second residue, heated again to 920° C., gave 7000 cubic feet of gas of analysis under heading "B."

	"A."	"B."
	Per cent.	*Per cent.*
CO_2	27.2	7.0
C_nH_n	5.5	1.2
C_2H_4	3.2	1.1
O_2	.7	.5
CO	9.2	22.5
CH_4	38.4	18.3
H_2	12.0	41.8
N_2	3.8	7.5

Evidently from these tests decomposition gradually brought about by heat tends to drive off at first the high oxygen content, and each coal type is converted into a type similar to, though not exactly like the succeeding higher grade fuel.

In the case of wood, the gas first evolved contains about 97 per cent. of CO_2 and CO. Similarly the lignites and Illinois coals first give off a high percentage of oxygenated compounds, and in this way necessarily the residues contain less oxygen and are of higher calorific value.

Under high pressures doubtless a sharper fractional decomposition would result, and the residues even more closely resemble the natural fuels.

At any rate, such slow, artificial carbonization is strikingly suggestive of nature's process. These residues show decided resemblances to the natural product. That they are not identical, both physically and chemically, may be due to the high pressure used in nature which we have made no effort to duplicate.[5]

[5] Results obtained by Ralston, U. S. Bureau of Mines, when plotting the composition of coals by the ingenious triangle method, indicate that the curve of decomposition bends strongly as semi-anthracite is approached, corresponding to the bend in our curve for calorific value of volatile matter.

NATURAL GAS A BY-PRODUCT OF COAL.

But if natural gas, chiefly methane and hydrogen, is a by-product of nature's carbonizing processes, we must explain the disappearance of the large amount of carbon dioxide and carbon monoxide which was originally present in such decomposition gases. May we not assume that the CO_2 has been absorbed from the gas by the alkaline earth waters produced by weathering rocks, and that the carbon monoxide has been absorbed and oxidized by metallic oxides?[6] Gas thus obtained from carbonizing lignite, for example, by removal of CO_2 and CO would be practically identical with natural gas. Thus, calculating out the CO_2 and CO from the gas obtained in heating lignites at low temperatures, we have left a gas containing principally methane, *i.e.*, a typical natural gas.

CLASSIFICATION OF COALS.

Now that we understand the nature of coals as different residues in the progressive decomposition of wood into graphite, we are in a position to classify them. Rejecting accidental impurities, such as ash and sulphur, and using the pure coal basis, coals may be classified in several ways. Five important differences are suggested on the following chart as bases of classification; for example, moisture, volatile, oxygen content, calorific value, and finally initial decomposition temperature. Specific gravity, total carbon, oxygen content, and other characteristics might also be given, all of which indicate the same progressive change in characteristics.

BETTER STANDARDIZED ANALYTICAL METHODS REQUIRED FOR VOLATILE MATTER AND MOISTURE.

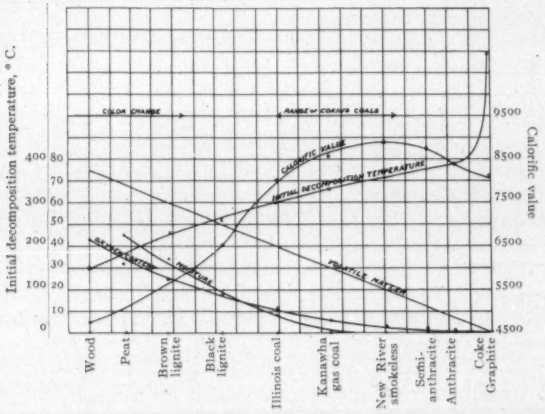
Unfortunately it is necessary to call attention to the lack of uniformity in methods of determining moisture and volatile matter in coals, since much of the data given in the tables pre-

[6] It is well known that CO in the presence of hydrogen can be oxidized to CO_2 without attacking the hydrogen by passing over metallic oxides. This selective oxidation is possible with ferric oxide and with copper oxide. Temperatures as low as 250° C. are sufficient.

sented depends in particular upon consistent results in the determination of these figures.

An atmosphere standing over a calcium chloride solution containing 35.5 per cent. anhydrous chloride will show a test

CHART VI.



at any ordinary temperature of 50 per cent. relative humidity. Likewise atmosphere in equilibrium with calcium chloride solutions will have the following relative humidities:

Calcium chloride.	Humidity.
Per cent.	*Per cent.*
26	60
12	40
20	50
30.5	30
35.5	70
41	90
45	80

A coal in such an atmosphere will, like any other hygroscopic material, take up and hold a definite amount of moisture according to its position among the types of fuels shown on the previous chart.

Volatile tests can be made with much satisfaction by use of the Meker burner, but perhaps for strict comparison standardized conditions in a muffle furnace are better.

Evidently as we progress in the series volatile matter, oxygen and moisture go down, while calorific values and temperatures of decomposition go up. As decomposition progresses the specific gravity also goes up.

I am not aware that the decomposition temperatures of coal types have ever before been studied, but since, as we have assumed, coals are residues representing the different steps in nature's carbonizing process under progressively severer conditions, it is only natural that they should have different, and, as we go up the scale, increasing temperatures at which they begin (again) to decompose. That these decomposition temperatures are progressively higher is a further strong indication that coals really are just such residues as has been assumed.

Low grade coals contain much moisture. They are in fact hygroscopic, and will, like other hygroscopic materials, when dried take up again moisture from moist air in proportion to its relative humidity.

As has sometimes been assumed, high volatile coals are not geologically new coals, nor are smokeless coals of an older geological formation, as is evident from the wide variations in volatile found in coals from the same geological seam. For example, the Pocahontas coals vary in volatile from say 16 per cent. in the true Pocahontas district, to above 30 per cent. in the equivalent geological New River district north of Meadow River, W. Va.

Though coals were formed from vegetation at the beginning of the carboniferous era, in the presence of more carbon dioxide in the air than later coals, this does not seem to have been the cause of any real difference in their character.

The classification, however, of coals on the basis of temperature required to decompose, is rational, as is strikingly shown from a study of coal deposits everywhere. In Washington State there are coals of all types from lignite to graphite, and, under different conditions, all types may be found in what appears to be the same geological horizon. When the seam is horizontal the coal is lignite; when somewhat disturbed and oblique the

coal is generally a gas or smokeless coking coal; when folded it becomes anthracite, and finally, when pierced by igneous rock, we have graphite.

COKABILITY.

In commercial work for our purposes coking coals have also to be classified as to cokability. In the following manner, which really is based upon oxygen content, though not requiring the tedious ultimate analysis necessary to give oxygen content, we have classified coals as to cokability, using as a basis the calorific value of the volatile matter contained. This, for coals of the same percentage volatile content, fairly represents cokability in actual coke oven practice.

CHART VII.

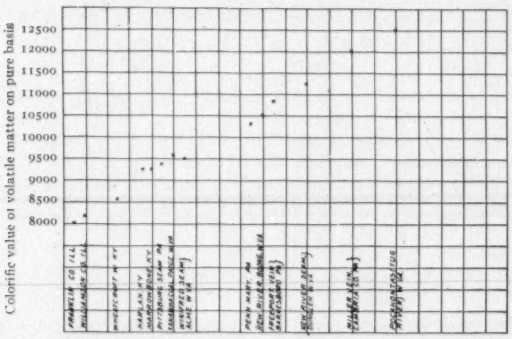


Table showing calorific value of volatile matter for typical coals of the United States.

On the previous chart (VI) the range of possible coking coals was indicated. Now, by deducting the calorific value due to fixed carbon (calculated) from the total calorific value, and dividing by the amount of volatile matter, all on the pure basis, we get a series of coals of increasing cementing or coking tendencies.

As shown on Chart VII, this variation in calorific value of the volatile matter has been found to represent results in actual coking practice.

As the calorific value of the volatile matter increases the cokability increases up to the point where the actual amount of volatile matter becomes insufficient to cement and hold the mass together. For example, semi-anthracite coals and anthracite, as to cokability, are beyond the limiting factor of insufficient cementing volatile material.

Cannel coal is unusual in that the calorific value of its volatile matter is higher than for any other coal with volatile so high. By the Ralston method of classifying and plotting it falls well above the usual curve.

Coals also differ as to the amount of materials contained capable of solution in caustic, pyridine, benzene and other solvents, and may be classified accordingly. So the residues from artificial carbonization at low temperatures give different amounts of matter soluble in the various solvents.

Finally, on exposure to moist atmosphere, coals decay. They become oxidized and go back in the series. For example, by taking up oxygen and water a good coking coal takes on the character of a poor sub-bituminous coal or the non-coking lignite.

Coals, and their by-products, are therefore not such mysterious materials. They are merely intermediate bodies resulting from the decomposition of ancient vegetation, just as a multitude of substances may be obtained by violent or gradual decomposition with heat of any simple organic compound.

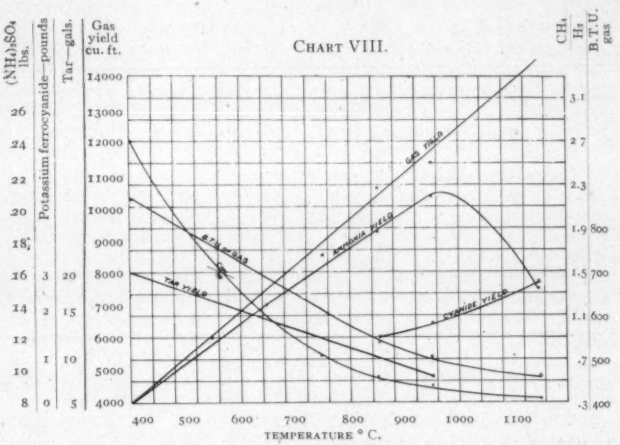
COMMERCIAL MANUFACTURE OF COKE AND BY-PRODUCTS.

The conversion of bituminous coking coal to its anthracite-graphite equivalent, coke, has become of extreme commercial importance, and particularly when this is done with the recovery of the by-products. A ton of average coking coal will produce in the modern by-product oven:

1500 pounds coke.
18 to 26 pounds sulphate of ammonia.
6 to 10 gallons tar.
1½ to 2½ gallons mixed light oils (benzole, toluole, xylole).
1½ pounds ferrocyanid.

By further elaboration, from these light oils and tar practically all the compounds mentioned in Beilstein may be produced.

On Chart VIII is indicated the influence of temperature upon the yields and character of the by-products obtained from an average coking coal. The temperatures given represent the hot-



test part of the retort at the beginning and end of the carbonizing period. The average temperature would be considerably lower.

On this chart the yield of light oil is not given, but our experiments indicate a maximum yield of this material at about 500° to 550° C.

VIRGIN COAL FIELDS IN THE UNITED STATES.

With this article are given some pictures selected from photographs taken by the writer to illustrate conditions in the virgin coal fields of the United States. These good Americans, with conditions of living which the discoveries of Koch and Pasteur have not yet reached, represent a backward glimpse into the frontier life of our own colonists' forefathers; this log cabin, timber clearing, horseback, spinning-wheel life with its quaint Shakespearean dialect is rapidly passing. A permanent record of some of these things is not, therefore, without scientific value.

Precipitation of Gold and Silver in Cyanide Solutions by Carbon. R. K. COWLES. (*Trans. Australasian Inst. Min. Eng.*, xvi, 58.)—In treating tailings, which also contained half-burned coal, etc., from power plants, by fine grinding in a weak cyanide solution for the recovery of gold and silver, it was found that the coal caused first the selective precipitation of the gold and later of the silver. Experiments showed that ground clinker, half-burned coal, and charcoal were all effective, but that unconsumed coal-dust had no action. The action appeared more rapid with fresh carbon than with carbon that had been saturated with water. The trouble was overcome by passing the tailings over vanners to remove the carbon.

Damascene Steel. W. GUERTLER. (*Int. Zeits. Metallog.*, v, 129.)—Damascene steel contains 1.0 to 1.6 per cent. carbon, and consists structurally of extremely small grains of cementite in a ground mass of ferrite. The characteristic appearance and properties of the steel are due to alternations of cementite-poor and cementite-rich zones. Prolonged heating at high temperatures, as recommended in the earlier literature, cannot possibly give the desired result. The most promising method seems to be to heat suitable steel, in which an extremely fine-grained structure has been induced, to a temperature below 700° C. for a sufficiently long period. The necessary preliminary structure may be produced by very rapid cooling, or by severe working above the eutectoid temperature.

Iron Ore Output of the World. C. K. LEITH. (*Times, Eng. Suppl.*, Feb. 4, 1913.)—The annual output of iron ore in the chief producing countries during the latest period (average of 1909, 1910, and 1911) for which the figures are available, was: United States, 50 million tons; Germany, 27; United Kingdom, 15; France, 14; Spain, 8; and Sweden, 5 million tons. Continued heavy production may be expected of the Lake Superior ores, the ores of the Franco-German boundary, the Bilbao ores of Spain, the Cleveland ores of England, and the high-grade magnetites of North Sweden; while increasing quantities of ores may be expected from Sweden and Cuba, and the use of Clinton hæmatites and Adirondack magnetites in the United States will also probably increase. In the near future there will probably become available the Brazilian high-grade hæmatites, Chilean ores, and ore deposits of the western United States, western Canada, India and China.

Non-Freezing Solutions. ANON. (*Amer. Mach.*, xl, 5, 186.)—"Compressed Air" points out that a mixture of 20 per cent. alcohol and water will not freeze above 10° F., 30 per cent. above 0° F., 35 per cent. above 10° below zero F., 40 per cent. above 20° below zero, and 50 per cent. above 35° below zero. The best alcohol is denatured grain (ethyl) alcohol.

CHANGES OCCURRING IN OILS AND PASTE PAINTS, DUE TO AUTOHYDROLYSIS OF THE GLYCERIDES.

BY

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In seeds of the oil-producing type, enzymes are known to exist, which have fat-splitting properties and which exert a marked influence upon the metabolism of the growing plant. That these enzymes may continue their action, even when the oil from the seed is used for some commercial purpose, has probably never occurred to the student of paint technology. In previous investigations,[1] the writer has referred to the possibility of oil hydrolysis by enzymes, and has described the hardening action of free fatty acids upon various pigments. As a result of more recent work, the writer is convinced that many of the phenomena referred to are due to the action of enzymes. The data presented below include suggestive measures for preventing such action.

A majority of paints are made of linseed oil (pressed from flaxseed) as the chief constituent of the vehicle or liquid portion. Plant pathologists have recently shown that flaxseed is sometimes infected by a certain type of wilt or micro-organism which presents the proper development of the plant resulting from the growth of the seed. The yield and character of flaxseed produced by such plants are low and unsatisfactory. It is probable that crushers have at times received shipments of such seed, especially during years when small crops were obtained. When such seed is crushed for its oil content, part of the micro-organisms in the seed passes into the oil. The sediment or " foots " present in all raw oil is made up largely of mucilaginous and nitrogenous matter which affords an ideal sprouting medium for micro-organisms. The small percentage of moisture present in raw oil is also favorable to their growth.

[1] Notes on the Formation and Inhibition of Mildew in Paints. Journal Franklin Institute, January, 1913.

The Effect of Pigments upon the Constants of Linseed Oil. Journal Franklin Institute, October, 1912.

The Effect of Pigments Ground in Linseed Oil. Journal Ind. and Engrg. Chem., September, 1911.

Flaxseed is usually steamed, previous to expression, in order to break up the oil cells and render the expression more complete. This steaming process is usually conducted at relatively low temperatures which do not destroy the micro-organisms present. Spores may therefore be left in the seed, which may later develop micro-organisms identical with those present before the steaming process. These micro-organisms require food for their continued growth. In order to obtain such food, they evolve certain enzymes which have fat-splitting properties. It is the writer's belief that, under favorable conditions, the enzymes evolved by the micro-organisms present in crushed linseed oil energetically attack the oil and split it up into its component parts—free fatty acid and glycerin. Both of these substances are foods for certain types of micro-organisms. A freshly crushed linseed oil, of normal acid value of approximately 4, may contain enzymes capable of splitting up the oil and thus greatly increasing the acid value within a short time. If such oil is used in a paint containing basic pigments, trouble may ensue. After the oil has been split up, the fatty acid formed will react with the basic pigments and form metallic soaps which are not only insoluble in paint but which become annoying on account of their peculiar character. If the reaction has been strong and extended over a long period of time, difficulty may be found in brushing out such paint to a perfectly smooth surface.

The writer has recently examined a paste lead paint which was very granular in condition, and, as a result of the examination, is inclined to the opinion that the oil used in the paint was expressed from infected seed. This oil probably contained enzymes which split up the oil into its two component parts. The basic pigments in the paint neutralized a portion of the fatty acids which were set free, and thereby formed little lumps of insoluble fatty acid soaps which were apparently made up of the higher fatty acids. Another paste paint was examined and found to be very lumpy. The lumps could not be brushed out to a smooth surface. Some had the appearance of dried bits of paint skins. Others resembled lumps of wax. These lumps, upon analysis, were separated into a liquid fatty acid having an acid value of approximately 180, a solid fatty product having an acid value of 84, and a metallic pigment which was present in combination with a part of the organic acid as a metallic soap. The micro-organ-

isms in the oil paint may have had a selective action upon the lower fatty acids, thus leaving a concentration of the higher and more active fatty acids to combine with the basic pigment in the paint.

Previous to this investigation, the writer had obtained a sample of linseed oil which had been giving much trouble to pigment grinders. When this oil was used in making white lead paints, considerable thickening occurred after six months or a year. The oil was very cloudy in appearance. The following analytical results were shown:

Specific gravity	.9450
Iodine number	171.3
Saponification number	133.2
Acid number	4.1
Foots (per cent.)	9.0
Moisture and volatile matter (per cent.)	.68

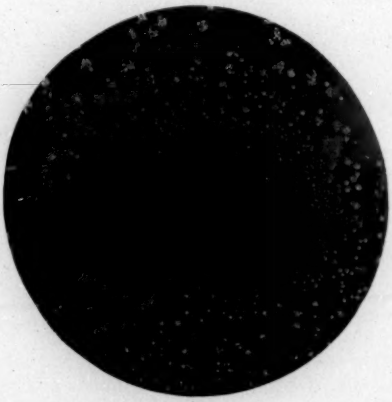
The large percentage of "foots" present had an acid value of 6.9. After clarification of the oil by repeated centrifuging, analysis gave the following normal constants:

Iodine number	177.3
Saponification number	190.2
Acid number	3.9

A sterile platinum needle was dipped into the "foots" obtained from the above described oil, and an extremely minute quantity was placed upon sterile agar-agar, gelatin and beef bouillon contained in test tubes. The tubes were placed in an oven at 37° C. At the end of 24 hours there was shown in each test tube a most marked development of white mould. Some of the incubated bouillon culture was then plated out upon agar-agar in petri dishes and again incubated at 37° for 24 hours. At the end of that time the surface of the agar was covered with microorganisms which were growing in profuse quantities (Fig. 1). Some of these were transferred to a microscopic slide, stained, and examined with an oil immersion lens. A distinct form of bacilli was plainly shown (Figs. 2 and 3). In appearance, the bacilli were similar to the hay bacillus which is known to exist in some kinds of grain.

A portion of the above described oil was then mixed with corroded white lead and thoroughly ground to a smooth, heavy paste. The paste paint was placed in an oven heated to 37° C. and allowed to remain there for one week. At the end of that time an examination of the paint showed a few tiny granules, indicating that some reaction had taken place. A portion of the oil was extracted and its acid value found to be two points higher than that shown by the original oil, thus indicating hydrolysis. The presence of mere traces of acetic acid, free carbonic acid and

FIG 1



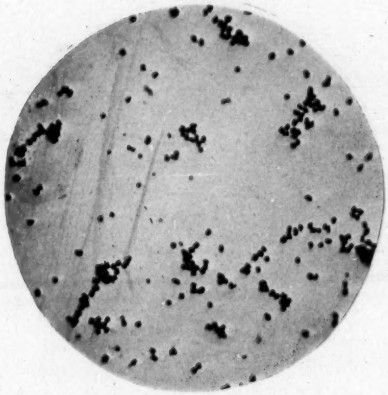
Colony of bacilli obtained from oil "foots" growing on agar agar.

moisture in white lead may have had an accelerating influence on the action of the enzymes. Such impurities probably act in a catalytic manner. Under favorable conditions, and with several weeks' time for reaction, much greater hydrolysis would have taken place. Within a year or two the lead paste might have become very granular. An experiment was then conducted to determine the effect of the micro-organisms present in the cloudy oil, when allowed to react with oils known to be free from such micro-organisms. A portion of the cloudy oil, which had shown a marked development of mould, was mixed with a sample of pure

linseed oil of known acid value. A few drops of water containing carbon dioxide gas were added. The acid value of the mixture was determined. At the end of forty-eight hours the acid value of the oil mixture was 10 per cent. greater than before.

Some experiments were then made to determine whether the bacilli in the cloudy sample of linseed oil could be destroyed by adding small quantities of antiseptic substances. The oil was distributed in test tubes and treated with small percentages of antiseptics such as cresol, carbolic acid, salicylic acid, sodium

FIG. 2.



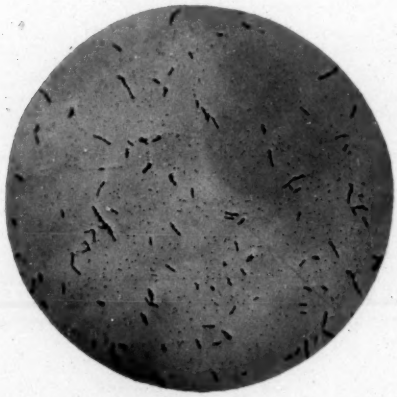
Mould spores obtained from "foots" of infected oils. × 1200.
Oil immersion lens. Green light filter.

benzoate, etc. Sterile agar was then inoculated with these samples of oil, and incubated. At the end of twenty-four hours a development of mould was shown upon each, thus showing that the above named powerful antiseptic substances had not destroyed to any marked extent the micro-organisms present in the oil.

An attempt was then made to determine whether the micro-organisms could be destroyed by heat. Samples of the cloudy oil were heated individually to 100°, 150°, and 200° C. As soon as the maximum temperature was reached, the oil was im-

mediately allowed to cool. By this process the constants of the oil were not changed to any material extent. Test tubes containing agar were then treated with these heated oils. At the end of periods of twenty-four hours, forty-eight hours, seventy-two hours, and one week, absolutely no development of mould was shown. Bacilli could not be found in the incubated agar. These experiments indicate that the presence of micro-organisms in linseed oil, which comes from poor seed, may be destroyed by rapidly heating the oil to 100° C., immediately withdrawing the

FIG. 3.



Bacilli obtained from " foots " of infected oil. × 1200.
Oil immersion lens. Green light filter.

heat to prevent oxidation, and allowing to cool. This heating process has the added advantage of rendering the oil clearer and better suited for general purposes. During the past, some manufacturers have used refined oil which has probably been heated during the process of refinement to the critical temperature noted above. For this reason, paints made of such oil have not deteriorated. On the other hand, some manufacturers have used raw oil which has not been refined or heated to 100° C., and such oil in some instances has probably been responsible for the granular condition observed in the lead paste.

It is interesting in this connection to record the condition of several prepared paints which were recently examined by the writer. These paints had been found among an old stock of supplies. They were packed in 1898. After sixteen years, no lumping, hardening or granulation had taken place. They were in perfect condition. Both lead and zinc whites were used in the pigment portion. The result of this examination would indicate that properly prepared paints made of good oil are capable of remaining in good condition for many years in sealed packages.

Since making the above outlined experiments, the writer has made a search of the literature bearing on the metamorphosis of oils, and has found several instances of the development of fatty acids in abnormal amount. Crampton [2] examined butter that had been kept in his laboratory for three years. The acid value had risen in that time from 5 to 109. He attributes this change to the action of moulds which were identified as Coniosporium and Pennicillium (?). Similar experiments on butter were conducted by Koenig, Spiechermann and Bremer,[3] who attribute the action to enzymes evolved. Lewkowitsch [4] refers at length to the fat-splitting properties of enzymes, and points out the better keeping properties of lard rendered by steam at 100° to 120° C. as compared with neutral lard rendered at a low temperature not sufficient to destroy all of the enzymes present. Lewkowitsch also refers to the rancidity developed in a sample of palm oil, which had been kept away from light and air, as proving that enzyme action can take place in oils stored in closed containers.

It has occurred to the present writer that the rancidity of many oils could be prevented by inhibiting enzyme action. For instance, it is quite possible that the odor of fish oils is due to the development of evil-smelling free acids developed by enzyme action. If fish oils were treated immediately after pressing, it is possible that better smelling products could be secured from marine animals. That the study of enzyme action should extend to other oils used in the manufacture of paint and varnish seems to the writer as most important. Many of the peculiarities of such oils as tung and lumbang might receive more satisfactory expla-

[2] Journal Amer. Chem. Soc., 1902, 24–711.

[3] Zeitschrift Unt. Nahr. und Genussmittel, 1900, 3–606.

[4] Chemical Technology and Analysis of Oils, Fats and Waxes. Lewkowitsch. Vol. I, 37–38.

nation as a result of such studies. It is also possible that new light might be thrown upon the interesting subject of oil synthesis.

In summing up the results of the present work, the writer would call the attention of the oil crusher to the advisability of heating raw linseed oil to at least 100° C. previous to shipment. Oil which has been treated in such fashion is "immune," or "sterile," and will therefore be found much more satisfactory for grinding basic pigments having a lead or zinc base. The writer would also call attention to the necessity of using well-filtered oils. Oils having a large percentage of "foots" are always dangerous to use with basic pigments.

The writer desires to acknowledge the valuable assistance of Thomas M. Rector and W. G. Abbott in the microscopic and photographic work.

Non-corrosive Lead. ANON. (*Brass World,* x, No. 2, 63.)—Lead containing a small percentage of antimony or tin is much more non-corrosive than the pure metal. Lead pipe made from scrap resists corrosion better than pure lead. Specifications for lead cable frequently require that the lead coating of the insulated wire shall contain three per cent. of tin.

The Influence of Manganese on the Mechanical Properties of Gray Cast-iron. F. WÜST and H. MEISSNER. (*Ferrum,* xi, 97.)—Four series, each series containing 10 samples, were prepared with manganese varying from 0.2 to 2 per cent. in each series; total carbon about 2.79 per cent. in the first series, 3.08 in the second, 3.32 in the third, and 3.89 per cent. in the fourth; silicon about 1.5 per cent. in the first three series, and 1.7 per cent. in the fourth. Mechanical and microscopic tests were made on all the samples. The members of the fourth series, with the highest carbon content, gave markedly the lowest "strength" results. Of the other three series, the second, in which the combined carbon most nearly approached 0.9 per cent., gave the best results. In the fourth series the strength increased with the increase of manganese due to the graphite lamellæ becoming smaller. In the first three series, tensile and transverse strength attained a maximum with about one per cent. manganese. Flexibility and impact strength fell with increasing manganese, the effect being greater the lower the carbon content. Hardness rose with increasing manganese, but for the low manganese values it remained practically constant in consequence of the increasing separation of graphite. The formation of graphite increased as the manganese content rose to 0.3 per cent., but the higher amounts up to 2.5 per cent. had no further effect.

LIGHT SIGNALS.*

A DISCUSSION OF THE OPTICS, SOURCES OF ILLUMINATION, AND MOST EFFICIENT DISTRIBUTION OF LIGHT FOR RAILWAY SIGNALS GIVING DAY AND NIGHT INDICATIONS.

BY

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CHAPTER IV.

LENSES AND REFLECTORS, INCLUDING A DISCUSSION OF PHANTOM INDICATIONS.

THE corrugated lens is generally used for signal lights on account of its cheapness, small weight, and more uniform cross-section. Where colored glass is used a fairly uniform cross-section is desirable, as otherwise the centre of the lens would be decidedly darker than the periphery. The corrugated lens is better adapted to pressing, and, as the expense of grinding is prohibitive in the case of signal lenses, the accuracy with which the corrugated lens can be pressed or moulded is a point in its favor. In Fig. 30, A represents a typical corrugated signal lens, and B represents a solid double convex lens having the same diameter and focal length; note the lighter construction and more uniform cross-section of A. For a more detailed discussion of the signal lens the reader is referred to a paper entitled "The Optics of the Signal Lens," by Dr. William Churchill (*Railway Signal Association, Annual Proceedings*, 1906).

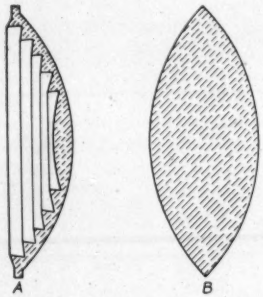
Assuming a source O, Fig. 31, projecting light equally in all directions: the fraction of the total spherical candle-power projected by the lens is $\frac{1 - \cos \frac{B}{2}}{2}$, and therefore increases with the angle B which the lens subtends. B is known as the "aperture" of the lens, and is limited by the total reflection of ray OX in the direction XS when the deflected light AX strikes the convex face of the lens at the critical angle.

For the ordinary "smooth-face" lens common practice has fixed 80° as the greatest value of B, chiefly with the purpose of

*Continued from page 408.

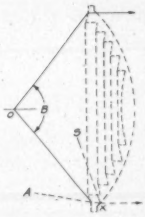
avoiding wasteful dispersion of light on the lens steps. By employing suitable lenses or combinations of two or more lenses, it has been found possible to increase the aperture considerably, and by increasing the value of B to secure greater "geometrical efficiency." We shall use the term "geometrical efficiency" to describe the percentage of total spherical candle-power impinging on a lens or reflector. We should conclude from this that the two lenses illustrated in Fig. 44 are more efficient than the ordinary signal lenses, as each have considerably larger aperture. However, the increase in "geometrical efficiency" does not add to the axial intensity of the projected light, its effect being to increase the spread. It does not neces-

FIG. 30.



A Fresnel lens and its equivalent.

FIG. 31.



sarily follow that the lens having the greatest aperture is best suited for signal purposes. Different lenses and reflectors cannot be compared directly on this basis, as much candle-power may be lost by reflection or refraction of light at large angles; nevertheless geometrical efficiency deserves careful consideration as it is an important factor in securing the maximum effective illumination.

The adoption of a single concentrated filament lamp at the focus makes the parabolic reflector a possible substitute for the lens. A formula for the geometrical efficiency of the parabolic reflector illustrated in Fig. 32 is submitted herewith, it having been developed by Messrs. M. D. Cooper, of the Engineering Depart-

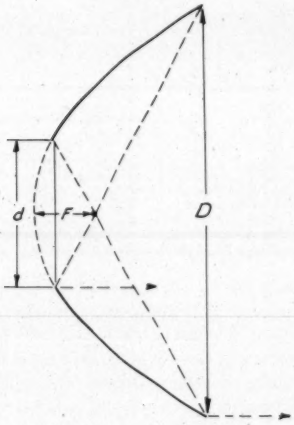
ment, and C. E. Terry, of the Brilliant Electric Division of the National Lamp Works of the General Electric Company.

E equals geometrical efficiency (per cent.).
F equals focal length.
D equals diameter of front opening of reflector.
d equals diameter of opening in back of reflector.

$$E = 400F^2\left[\frac{1}{4F^2+\left(\frac{d}{2}\right)^2} - \frac{1}{4F^2+\left(\frac{D}{2}\right)^2}\right].$$

Before discussing the merits of different forms of light projectors, it is necessary to consider the limitations incurred by

FIG. 32.



Parabolic reflector. Geometrical efficiency.

safe design. To secure the greatest efficiency a parabolic reflector or a lens combined with reflector should be used. Referring to Fig. 33, it will be evident that light can enter either of these light signals and be reflected back in such a manner as to present an apparently illuminated signal.

Phantom indications are both undesirable and unsafe, and careful consideration should be given to means for eliminating

them. Especially where electric head lights are used, or where signals are located so that sunlight may at some time during the day shine directly into the lenses, every precaution should be taken to eliminate all possibility of phantom indication. To avoid phantom signals with a lens, it is necessary to omit the reflector *A*, Fig. 33, or to relocate or use only part of said reflector. In addition to this, a careful study should be made of the effect of all glass parts in the vicinity of the focus as these may become sources of phantom indication.

To avoid phantom signals from reflectors it is necessary to employ special designs of reflectors combined with certain interference rings and shields designed to prevent external light entering the light signal from being reflected back in the observer's

FIG. 33.

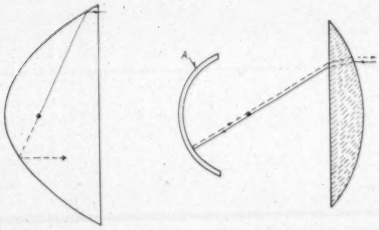
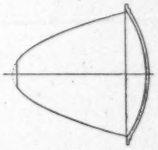


FIG. 34.



eyes. The complication in design incident to the avoidance of phantoms may thus develop into a serious argument against the use of reflectors in light signals.

The author does not believe it necessary to describe the numerous schemes which have been proposed and tried during recent light signal development, but it should be understood that very careful investigation has been made to determine the causes of phantom signals and the best means of avoiding them, with the result that it is now possible to design a signal on which numerous tests, both in sunlight and with powerful head lights at night, show that no perceptible phantom may be anticipated.

In this connection it is interesting to note that where glass "roundels" are used these should be made convex as shown in Fig. 34. Unless this is done the glare of light reflected from a plane glass roundel may be sufficient to blot out the signal indication.

Cases have also been observed of colored roundels where reflection from a rear face of a plane roundel was sufficient to give a distinct colored indication.

To analyze the different types of lenses and reflectors which have been considered in designing a light signal, or to attempt to compare their merits, would require more space than can be allowed at the present stage of the subject. For commercial reasons the author has found it best for the present to adopt the single concentrated filament lamp and with that lamp to develop the best optical combinations for immediate practical application.

FIG. 35.

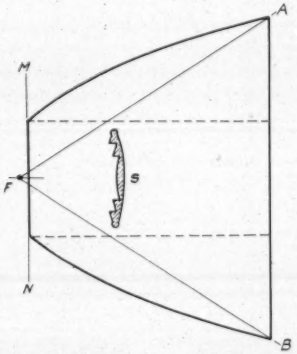
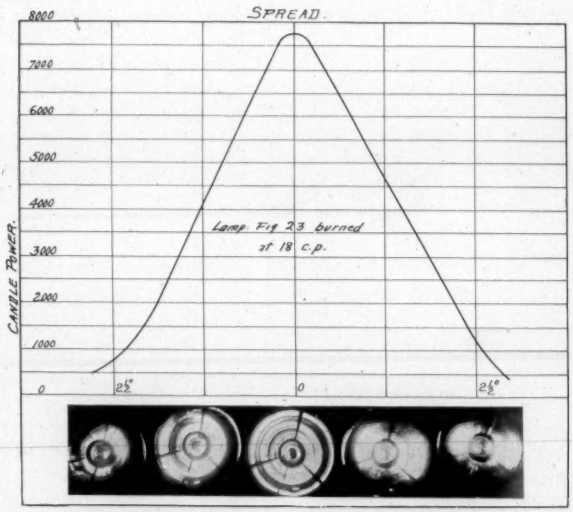


Fig. 36 shows photographs and candle-power distribution of light from the combination of reflector and lens shown in Fig. 35. This combination of reflector and lens is the result of extensive tests which it is unnecessary to describe here, but which determine the best size and focal length for both. There are many things which must be taken into account before it is possible to design an efficient reflector which will not present serious phantom indications where arc head lights are involved or where sunlight shines directly into the signals. The combination covered by Figs. 35 and 36 has geometrical efficiency of about 35 per cent. and represents the best results which it is possible to secure with absolute safety; it serves, therefore, as a fair basis for the comparison of the reflector with the lens.

The type of lens to be used depends entirely upon the spread and candle-power considered necessary and the type of lamp available. As already noted, a large spread and low candle-power can readily be obtained by using a large lamp filament; such distribution of light is well illustrated by the candle-power curve on Fig. 24, using the 25-watt, 110-volt standard Tungsten lamp. Where good color indications are required at distances of 2000 feet or

FIG. 36.



Combination of 3-inch lens and 10-inch metal parabolic reflector.

more in broad daylight, experience has shown that a high beam candle-power is necessary, and for such conditions we need, in addition to a concentrated source of light, a lens of high efficiency which will be capable of projecting a highly concentrated beam of light. The best type of lens cannot be determined without knowing the size and shape of the lamp filament.

The concentration of light at the focus of the lens obtained by using a compact incandescent filament similar to Fig. 23 is, of

course, of the greatest importance. We show, however, on Fig. 44, two candle-power curves which illustrate the influence of the lens itself in projecting light. These curves represent two typical lenses, each having the same lamp filament at the focus. The lenses shown in Fig. 44 are submitted only as an interesting comparison, and do not necessarily represent the best construction which is possible. In fact the development of high candle-power light signals is yet too much in its infancy to warrant any definite statement at this time as to the best type of lens to be used.

Our experience to date would indicate that the lens is more desirable than any construction of parabolic reflector so far developed. Moreover, the lens costs less than the parabolic reflector of anywhere near equal efficiency, and it seems evident that dust, frost or "sweating" will have less effect in impairing its efficiency. To offset the increased cost and the greater efficiency depreciation to be expected in service, it would be necessary that the parabolic reflector show decidedly higher candle-power than could be obtained with any lens.

CHAPTER V.

CANDLE-POWER: ITS RELATION TO RANGE OF LIGHT SIGNALS.

In developing a satisfactory signal we should aim to secure a minimum range of 1500 to 2000 feet under the most unfavorable weather conditions which can be encountered. Unfortunately, we are still confronted with the occasional necessity of locating signals on sharp curves or where obstructions exist which prevent a clear range of even 1500 feet; this problem can be solved only by care in locating signals or providing overlap protection for those signals which cannot be properly located, and this condition does not invalidate the arguments for long range which have been offered in the first part of this article. Light signals show up best where they have some background; in fact, those locations commonly considered undesirable will generally be found best for these signals. The light signal is least distinct when displayed on a sky background with the sun in the observer's face; obviously, therefore, tests for candle-power and range must be conducted under these unfavorable conditions.

In this connection it might be noted that where either candle-power or candle-foot illumination is mentioned the same is based

on uncolored light; the colored glass used for light signals will reduce the effective candle-power to between 10 per cent. and 20 per cent. of the uncolored light.

A large number of field tests have been made with signals of different candle-power, employing lenses or reflectors of different sizes and equipped with roundels of different colors and densities. These tests have afforded conclusive proof that the visibility of a signal may be measured by the candle-foot illumination which this signal projects upon the observer's station. Theoretically, the candle-foot illumination necessary for visibility should be uniform at all ranges. A little study of conditions will make it plain that, owing to the decreasing prominence of the background on the longer ranges, the light has less of the black backing so necessary to set it off properly. As the range increases the light itself presents a smaller object to the eye, which makes it increasingly difficult to distinguish color accurately.

To correct for the conditions just outlined, it is necessary to employ a background of liberal size (3 feet to 4 feet diameter has been favored) and to increase the diameter of the lens. Of two lenses projecting beams of the same intensity, the larger lens will be visible at the greatest range as it presents the larger object to the eye. It is also necessary to increase the candle-foot illumination with the range, in order to correct for the decreasing prominence of the signal, making the candle-foot illumination for a 2500 foot range several times greater than that necessary for a 1000 foot range. This will, to a great measure, compensate for the difficulty experienced in recognizing colors. It is also desirable to establish some minimum candle-power at ranges under 600 feet, and not attempt to apply the candle-foot rule, which would here result in ridiculously low candle-powers. Of course, the candle-foot illumination necessary for visibility will show astonishing variations with slight changes in the weather and in the location of the signal. However, by taking the precaution noted above and securing data under the most unfavorable conditions, a set of candle-foot values may be obtained which will eliminate an endless amount of work by providing an accurate formula for calculating the candle-power necessary for any type of signal, once the desired range is assumed. Thus, to determine the candle-power of a signal where range must be 1500 feet, make

$C.P.=i(1500)^2$ where i is the proper candle-foot value selected from the standard data.

In practice the author is convinced that it will not be difficult to find advantageous locations for light signals, especially in congested territory and where bridges on the right of way offer good background, and that where light signals must be located with sky backgrounds and the morning or evening sun behind the signal the disadvantage of location may be offset by applying larger backgrounds to the signals. In foggy weather the high candle-power light signal gives very satisfactory service, there being little trouble in getting distinct signal indications at 1000 or 1500 feet, as desired. It is in just such weather that we are apt to experience the greatest delay in moving traffic and at the same time incur the greatest risk of engineers overrunning signals in an attempt to make up time.

Reference to the exact candle-foot values necessary for visibility has been avoided, as these values are directly influenced by the density of the colors used, and color is a subject on which different railroads may not at once agree. For a further discussion of colors the reader is referred to Chapter VIII.

CHAPTER VI.

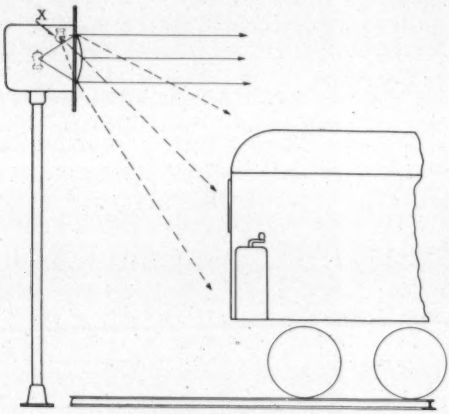
DISTRIBUTION OF LIGHT.

On straight track a signal need have only enough "spread" to permit convenient alignment. Experiments under practical operating conditions show that about 2° total spread will permit reasonably convenient alignment on tangent track. To make it possible to see the signal indication when standing close to the pole or bridge on which the signal is mounted, it is necessary to project a small percentage of the light downward. Engineers frequently have occasion to read the signal indication when standing very close to the signal (see Fig. 37), and it is important that this indication be perfectly definite, as if we permit any indistinct glitter to be taken as a signal indication we increase the danger of a phantom signal.

It is a practical certainty that with the precautions already cited no phantom will be observed which can be confused with the brilliant illumination of the light signal when viewed from straight ahead. Three devices have been used to provide

a definite indication to the engineer standing nearly below a signal; the most obvious is to use a signal light with a great spread, but this is decidedly uneconomical, as it involves a fila-

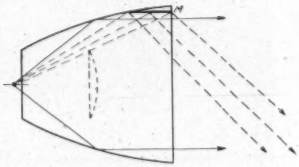
FIG. 37.



An auxiliary light for short ranges.

ment of large area, only a small portion of which is really useful for long-range indications. The second device comprises one lamp at the focus of lens, and a second lamp of less candle-power

FIG. 38.

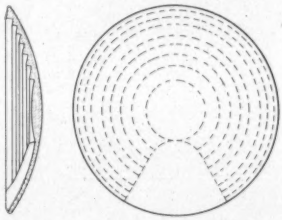


if desired, located at *X*, Fig. 37, so as to project light downward. The arrangement shown in Fig. 37 has given practical and satisfactory service for several years; the only objection which may be cited against it is that two lamps are necessary and that one

of these is inefficient and practically useless for long-range indication.

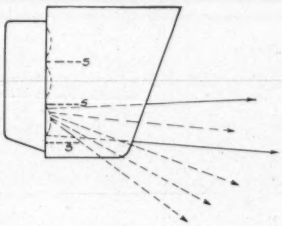
The "pilot light" *X*, Fig. 37, may in some situations be justified by its useful function as a marker. Where an independent marker *A*, Fig. 25, is employed, especially on single

FIG. 39.



track blocking, the failure of a signal light results in a stop signal and it may be necessary to flag a train through the block. By using the pilot light *X*, Fig. 37, as a marker, failure of the signal light results merely in a short range indication: the engine runner will be compelled to slow up but need not come to a stop, and can

FIG. 40.



Shields to prevent engine runner standing directly under signal.

enter the block with a perfectly clear signal indication. In this case the same arguments presented for Fig. 25 apply, a rugged lamp of long life being indispensable. Of course, the pilot lights *X* are controlled through the same relay contacts which control the signal lights; a defective relay contact may thus result in the

absence of any indication, an accident impossible with the marker light *A*, Fig. 25, which is burning continually and is not dependent on contacts of any description.

FIG. 41.

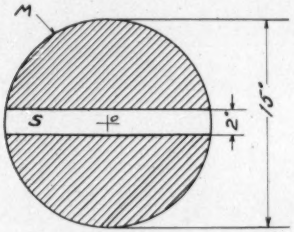
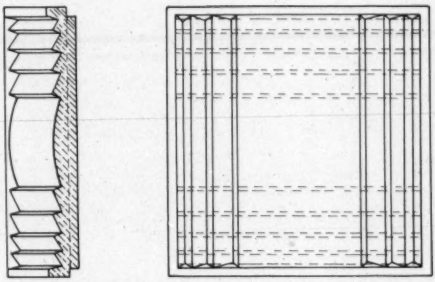


FIG. 42.

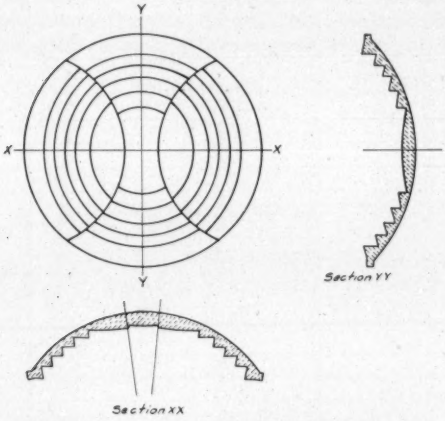


Lenses designed with more horizontal than vertical spread.

In the third scheme an independent repeater signal of low candle-power is connected in multiple with the green signal light and located as shown in Fig. 48, so as to be visible within that portion of the track near the signal not covered by the light signal

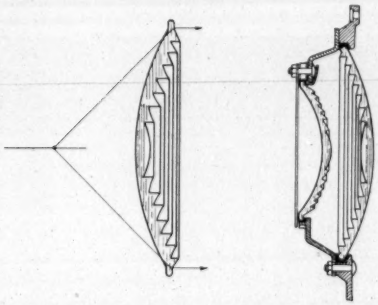
proper; however, this involves not only extra lamps but an extra signal and wiring as well.

FIG. 43.



Lenses designed with more horizontal than vertical spread.

FIG. 44.

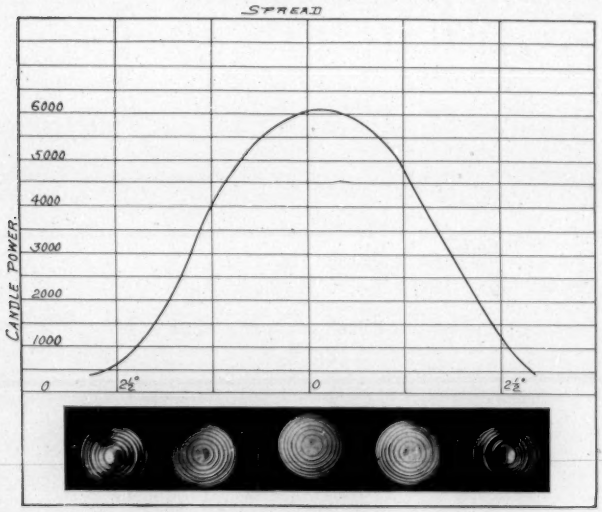


Inverted lens. Combination lens.

The author believes it better to use only one lamp in each signal, and either to locate reflectors *M*, Fig. 38, in some position to project a portion of the light down to that portion of the track

close to the signal, or else secure the same result with a lens shown in Fig. 39 having a small portion of its surface free from corrugations, so that the lamp can be clearly seen. It is not necessary that an engineer stop directly under a light signal; he can just as easily be required to stop 25 feet or 50 feet before he reaches the signal; to prevent the engineer from approaching so close that

FIG. 44A.



Combination lens. Lamp, Fig. 23, burned at 18 c.p.

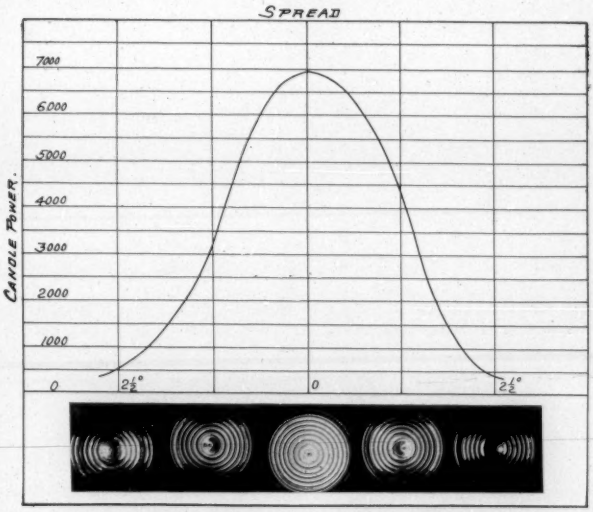
he cannot definitely recognize the signal indication it is best to equip each signal with shields *S*, Fig. 40, so designed that the engineer cannot see the signal indication if he approaches closer than 25 to 50 feet; with this arrangement you either get a distinct signal or none at all, and there is no opportunity for an engineer to stop in a position where he must either back up or take a guess at a doubtful indication.

Wherever possible, signals are located on tangents; very many signals must be located on curves, and we are, therefore,

confronted with the necessity of distributing light through a comparatively wide angle with as little waste of power as possible.

The light projected from a lens or reflector may be spread uniformly around the axis *O*, Fig. 41, which represents a beam of light projected on a screen, by increasing the area of the source of illumination or by placing this source out of focus; in Fig. 41,

FIG. 44*B*.

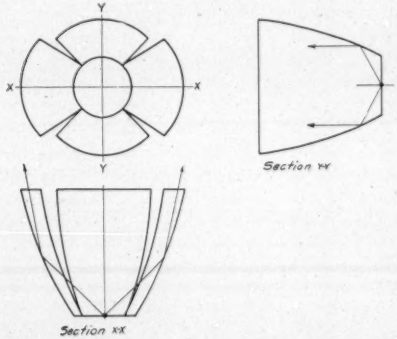


Inverted lens. Lamp, Fig. 23, burned at 18 c.p.

M represents the circle in which this light would be projected upon a screen. The spread in a horizontal plane must in many cases be 15°, often more; the vertical spread need only be enough to make alignment reasonably easy, say 2°, as the variations in grade of track will usually not require more than 1° vertical spread; hence the required distribution of light is indicated by *S*, Fig. 41, and the shaded area included between *M* and *S* represents wasted light.

The horizontal spread can be increased with relation to the vertical spread by placing a long incandescent filament at the focus, horizontal and at right angles to the axis; this involves some waste of power, as only a small percentage of the filament is at the focus, and the remainder, being out of focus, projects light inefficiently. Or the filament can be concentrated near the focus and the lens or reflector be designed to spread light horizontally; thus in Fig. 42 the lens is compounded of two sets of prisms at right angles to each other, so that the horizontal and vertical spread may be regulated independently. We can thus disperse light in a horizontal plane and avoid unnecessary spread

FIG. 45.



A parabolic reflector designed for increased horizontal spread.

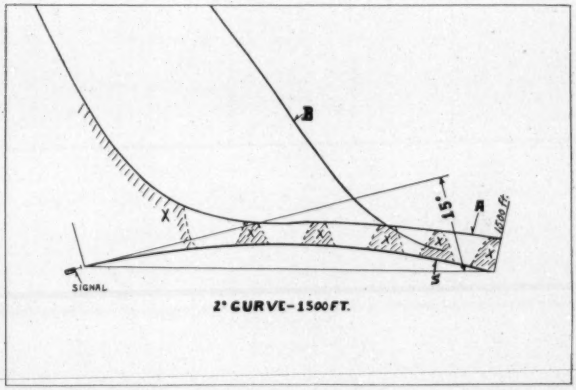
in the vertical plane; in Fig. 43 the lens is compounded of three sections, designed to project light on three different axes in a horizontal plane; Fig. 45 shows the same principle applied to a parabolic reflector, three segments of the reflector being aligned so as to project light along three different axes. In both Fig. 43 and Fig. 45 the light from the different sections is intended to overlap so that the signal may be seen through the entire angle.

Signalling on Curves.

Apparently no consideration has heretofore been given to designing a light signal to conform to the requirements of railroad curves. *S*, Fig. 46, is submitted as a typical curve; on this

curve as a base the line *A* is plotted, the distance between *S* and *A* at any point representing the candle-foot illumination required if the signal is to be clearly visible from that point. *A*, Fig. 47, is the candle-power curve corresponding to *A*, Fig. 46, and the reader will note that the symmetrical dispersion of candle-power provided by any of the lenses or reflectors previously mentioned is entirely unsuited to the purpose. As an example the author submits *B*, Fig. 47, the curve of a doublet lens with ½-inch 15 candle-power horizontal filament at right angles to the optical axis, and *B*, Fig. 46, illustrates the inefficient distribution of the

FIG. 46.



light from this lens along curve *S*, the illumination at the centre of curve being far higher than necessary, while the more distant portions of the curve do not get sufficient illumination. It is obvious that a signal designed to distribute light unsymmetrically per curve *A*, Fig. 47, will provide a greater spread, can be seen from a greater distance on curve, and yet can be operated with less lamp watts than any existing form of light signal.

To secure more uniform candle-foot illumination on a curve, we have worked along new lines and designed a combination of lens and parabolic reflector as shown in Fig. 49. The reflector is divided in two sections, having optical axes divergent: section *A*, projecting a major portion of the light, is to be lined up on the

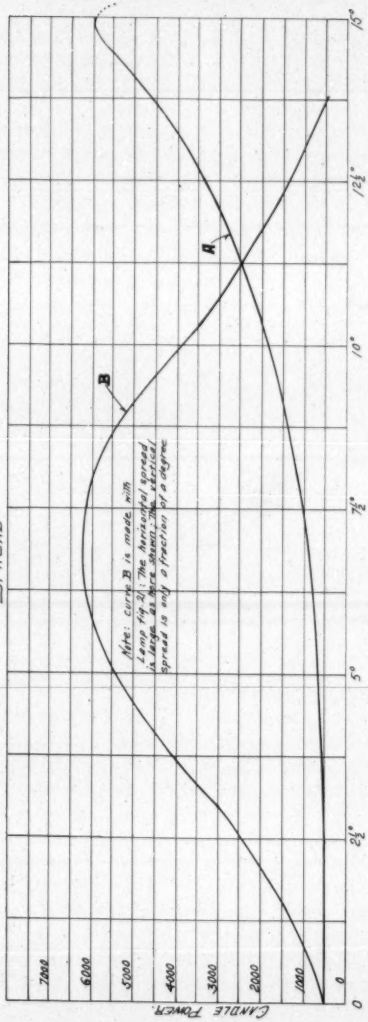
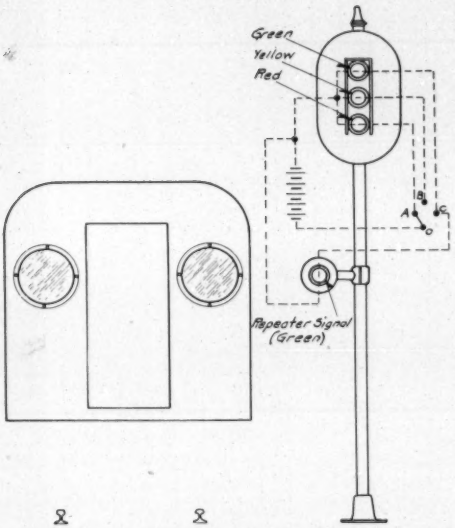

CANDLE POWER
7000
6000
5000
4000
3000
2000
1000
0
0
2½°
5°
7½°
10°
12½°
15°
A
B
Note: curve B is made with Lamp Fig 20. The horizontal spread is large as here shown; the vertical spread is only a fraction of a degree.
SPREAD

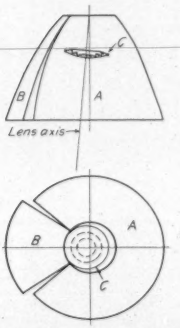
FIG. 47.

FIG. 48.



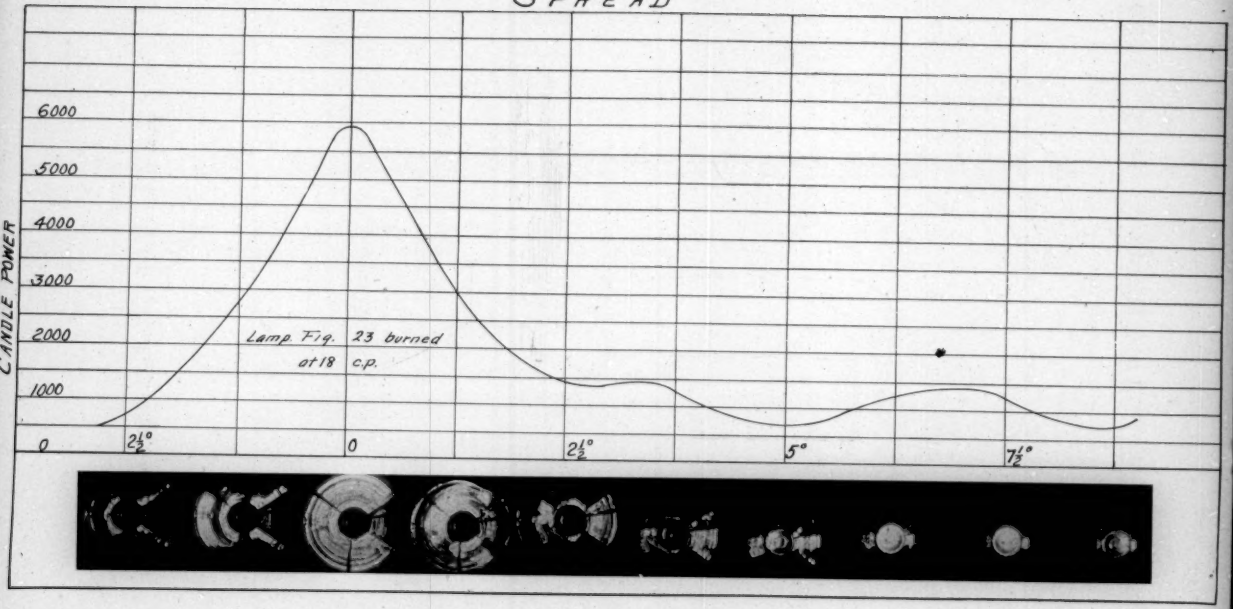
Repeater signal for short ranges.

FIG. 49.



A combination of lens and reflector for signalling on curves.

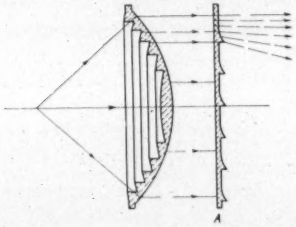
FIG. 50.



Combination of lens and parabolic reflector, Fig. 49, for curve alignment.

most distant portion of the curve, section *B* and lens *C* project other and smaller portions of the total candle-power over the remainder of the curve. The object is to secure more efficient distribution of light by projecting the higher candle-power on the remote ranges and lower candle-power on the nearer ranges.

FIG. 51.

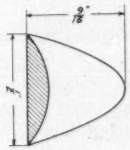


A refracting screen for signalling on curved track.

Fig. 50 includes photographs of the signal at different angles, and its candle-power distribution.

The signal shown in Figs. 49 and 50 does not meet requirements perfectly, as it concentrates light on three axes: to secure a perfect distribution of candle-power, as curve *A*, Fig. 47, it is best that some form of prismatic screen, as, for example, *A*, Fig.

FIG. 52.



Standard flat flame long time burner for semaphore.

51, be placed in front of an ordinary lens or reflector, the prisms comprising this screen having such form that the light may be distributed as required. This prismatic screen has the advantage of being an adjunct of the regular light signal, and may be built with different prism angles to cover various degrees of curvature up to about 40° central angle. When signalling on

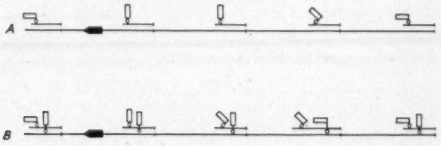
sharp curves, or under the necessity of increasing the brilliance of the light, the same general effect may be secured with the same lamp watts by concentrating the light flux at several points on the curves, the light distribution being as shown by *XX*, Fig. 46. For ordinary use on straight track the prismatic screen may be removed.

FIG. 53.

Spread of light from a semaphore lantern.

The standard semaphore signal is limited by the curves which can be included in the spread of the semaphore lantern. Most semaphore lanterns are equipped with five-day oil burners of the flat flame type, the flame of which is illustrated in Fig. 52; the use of the flat flame burner is nearly universal, and it appears to be giving good satisfaction. We have, therefore, measured the angle through which a standard semaphore lantern with clear

FIG. 54.



A. Overlap protection. *B*. Three block indication.

lens, red roundel, and flat flame (Fig. 52) can be seen on an average clear night, and find it will just satisfactorily include the curve, Fig. 53. In determining the angle (20°), the semaphore lantern was lined up so that in front of the signal one could see a fairly well-filled lens giving a distant indication. On the basis of these tests the author has concluded that a spread of 15° to 20° will meet average railroad conditions.

In certain exceptional cases where this is impossible either signals of great spread and correspondingly high wattage may be used, or the light be concentrated on several points on the curve,

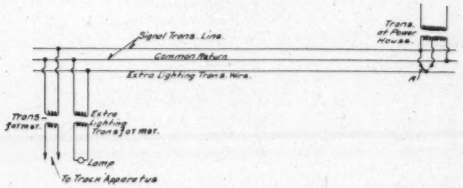
as shown by *XX*, Fig. 46, or, as the last resort, extra protection be afforded by providing overlap signals so that a train will either leave two danger and one caution signal behind it (*A*, Fig. 54), or one danger and two caution signals *B*.

CHAPTER VII.

REDUCTION IN CANDLE-POWER AT NIGHT.

When it is remembered that the present semaphore lantern with ½ candle-power oil flame (Fig. 52) projects a beam of 60 candle-power and gives a sufficiently brilliant signal for night indication, it is obvious that the light signal may prove far too brilliant at night; in fact, it is as powerful as a small automobile headlight. For this reason it would seem advisable to reduce the lamp voltage at night and thus lower the candle-power to about 500, which tests have shown not to be high enough to cause any annoyance.

FIG. 55.



Circuits for controlling voltage at night.

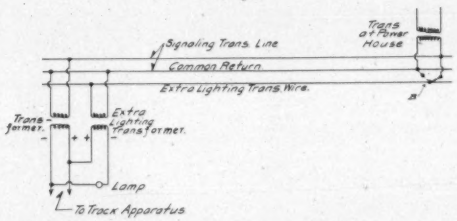
It would be impracticable to reduce the voltage at each individual light signal unless some automatic device could be designed for the purpose. The simplest arrangement is to control the lamp voltage on a section of light signals from the power-house or sub-station, thus placing the control of candle-power in the hands of a station attendant who can vary the candle-power to suit local conditions. The four diagrams, Figs. 55 to 58 inclusive, represent several possible methods of controlling lamp voltage from a sub-station.

Fig. 55 shows a method of voltage control obtained by adding a third wire to the transmission line and an additional transformer for the lamps at each signal location. This additional transformer is to be connected with the third wire, and one of the

signalling mains used as a common return. By varying the voltage between this third wire and the common return at the power-house, the voltage of the lamp can be varied. In this, as in succeeding figures, the term " Track apparatus " is used to designate the track circuits and the relays which in the alternating current system are supplied with power by local transformers connected to the signalling transmission line. These local transformers take the place of the batteries shown in Fig. 2.

Fig. 56 shows a somewhat similar scheme which enables the third wire to be smaller in size than would be required in Fig. 55, and operates as follows: The extra transformer is so wound that its secondary voltage is about one-half that required by the lamps. The secondary of the local transformer is connected in series

FIG. 56.

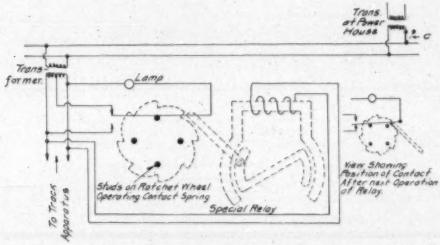


Circuits for controlling voltage at night.

with the secondary of this extra transformer and the lamp. If the power-house attendant short-circuits the third wire and common return by means of a switch *B*, the impedance of the extra transformer is reduced to practically nothing, which applies full voltage of the local transformer to the lamp; if through switch *B* voltage be applied at the power-house between the third wire and the common return, it will induce voltage in the secondary of the extra transformer, which, if the transformers are connected in opposition, reduces the voltage of the local transformer to one-half. The advantage of this scheme over the first one is that the power which is to be transmitted over the third wire is less than when this third wire had to carry all the power for the lamps. The extra transformers can thereby be made smaller in capacity. This reduction in power enables the third wire to be smaller in size.

The third scheme, as shown in Fig. 57, does away with the use of an extra transmission wire and consists of a relay used at each signal location, which by a pawl and ratchet arrangement closes one or the other of two contacts at each alternate operation. These two contacts may be connected to the transformer supplying the lamps, so that when one is closed the lamps receive full voltage; when the other is closed they receive one-half voltage. If all these relays on the signalling section be placed in step, in order to change the voltage the power-house attendant will merely need to open the circuit for an instant by means of a switch *C* and close it again. This will change the voltage on the lamps throughout the system, and in this way, unless an occa-

FIG. 57.



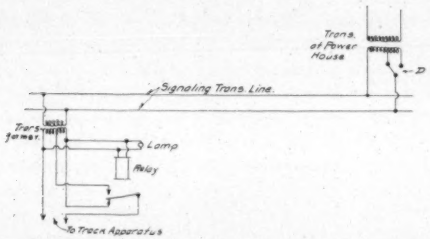
Circuits for controlling voltage at night.

sional relay gets out of step, the power-house attendant has control of all the lamps.

The fourth scheme, which also uses but two transmission wires, operates by varying the high transmission voltage by the percentage of variation desired in the lamps. This would introduce large variations in the track voltage, which in turn means wasted power and decreased safety, as the minimum voltage must be sufficient to operate the track relays, consequently a decided increase in voltage will over-energize the track relays and make it less easy for a train to shunt them and cause relay contacts to open. However, variation in track voltage may be avoided, as shown in Fig. 58, by connecting a relay to the transformer which will have its front contacts closed when high voltage is on the line, and its back contacts closed when low voltage is on the line. By connecting the front contact to the low tap on the transformer

coil which is supplying the track apparatus, and the back contact to the whole coil, it would be possible to maintain the same voltage on the track apparatus, while that of the transmission line would

FIG. 58.



Circuits for controlling voltage at night.

be varied. The transmission line voltage is here shown controlled by a switch *D*.

CHAPTER VIII.

COLOR.

General signalling practice has favored the use of green for clear, yellow for caution, and red for stop. An interesting discussion of color values is presented by Dr. William Churchill in his paper, "The Roundel Problem," page 337 of the 1905 *Proceedings of the Railway Signal Association*. For further reference to the ranges in color and transmission of light the reader is referred to the Railway Signal Association specification for roundels and to the spectro-photometric curves of average intensity signal roundels, and of different illuminants taken from data recently collected and here shown in Figs. 59 and 60.[1]

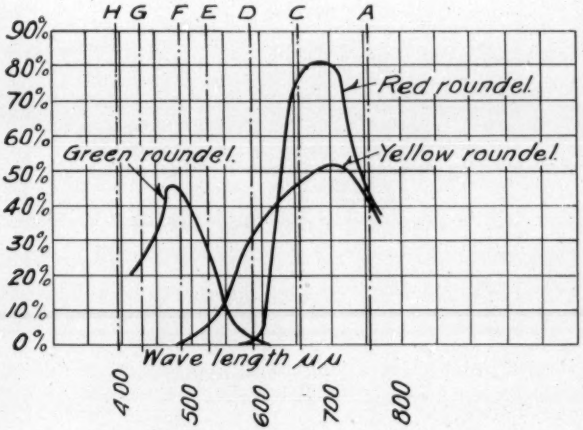
The Railway Signal Association transmission limits—green 75 to 125, yellow 80 to 120, and red 70 to 130—have the endorsement of many years of safe and satisfactory service for night indications of low candle-power. Reference to the Railway Signal specifications will show that standard red, yellow, and green glass are specified having spectro-photometric characteristics similar to the curves in Fig. 59: glass having such specific value is

[1] For information in compiling Figs. 29, 59, and 60 the author is indebted to Mr. Robert E. Morse.

then rated as 100, and roundels or lenses are measured simply by comparing the candle-power transmitted by the sample with that transmitted by the standard. Glass rated as 130 is, therefore, less dense and transmits 30 per cent. more light than the standard.

These limits are based on the oil flame; they have been used with low candle-power tungsten lamps and have apparently given satisfaction, although in theory a denser green and red should be used to compensate for the difference between the spectro-

FIG. 59.



Spectro-photometric analysis of different colored signal roundels.

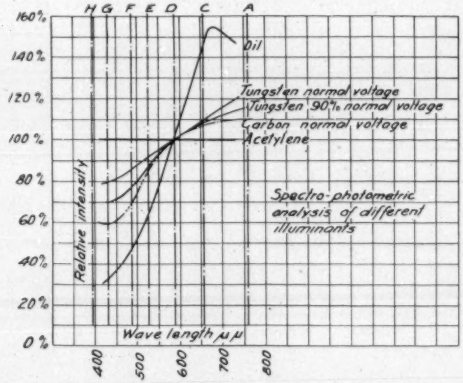
photometric curves of the oil flame and the tungsten filament as shown in Fig. 60. As we are now considering the proper color and transmission of glass for high candle-power signals, using tungsten filament for both day and night indication, some variations in transmission and color are advisable as outlined below.

GREEN.—In daylight, especially against a sky background, the average green shows too weak a color. To get a satisfactory range and fairly well-defined color, a low transmission green has been successfully used. This green will still provide a distinctive color indication at night, even with the high candle-power necessarily used.

RED.—With the candle-power used, average red may verge too closely upon the yellow, especially at twilight or on cloudy days. Experience has shown that an unusually low transmission is useful; even with this dense red it may prove desirable to cut out some of the orange on the *C* line, Fig. 59.

YELLOW.—It is important to get such a distinct yellow that it shall not be possible to confuse it at night with the yellowish light projected by a reflector from a tungsten lamp burning at reduced voltage in case the colored lens or roundel is removed, otherwise a broken red glass might be interpreted by an engineer

FIG. 60.



Spectro-photometric analysis for different illuminants.

as a caution signal; we wish a broken lens or roundel to be obvious and inform the engineer that the signal is out of order, and that he must stop and investigate. For this reason an unusually dense yellow is very desirable. On the other hand, we must be sure that the red is not light or the yellow dense enough to be confused in foggy weather at night or in the early morning. That there is a chance for this is obvious by noting the large amount of red transmitted by the average yellow roundel (see Fig. 59). If yellow and red are similar enough to be mistaken for each other in foggy weather, it may result in an engineer interpreting red as "caution" instead of "stop"—a very dangerous mistake.

By using the very dense yellow and red we increase the power necessary to project a satisfactory signal indication; on the other hand, this added power is necessary to give sufficient range to the green, as unless it is brightly illuminated it presents a very faint indication.

The most obvious advantage of dense colors and high candle-power is the certainty of detecting a broken roundel, there being no danger of mistaking it for a yellow. The increased density also adds to the richness of color, an important consideration in daylight signals.

The use of a position indication has been proposed as a substitute for colors. To present a signal without employing colors it is necessary to use two or more lamps to determine each indication, these lamps being placed behind the proper lenses and being preferably located along the centres of an imaginary semaphore arm so that the different indications will correspond in position to those shown on Fig. 1. The development of the position light signal has not yet reached the stage where any further comment is warranted.

The author would like to consider the relative economy in power secured with low wattage lamps as balanced against the possible increase in operation cost introduced by the more careful attention necessary to secure close alignment or the extra cost of specially constructed lamps. Obviously, each case must be treated on its individual merits; in some cases the high voltage (usually 2200 volts) signal mains will be made so large for mechanical strength that they will readily carry the extra load due to increased lamp wattage without adding anything to the first cost of the installation; and here we have only to consider the increase in operating cost due to power consumed. As this subject cannot be analyzed intelligently without description of various typical installations, the author believes it best to leave further consideration of the subject for future discussion.

CORRECTION.

Figure 63, page 391, April issue, should be figure 54.
Figure 69, page 401, April issue, should be figure 60.

Errors in the Interpretation of Tests for Electrolysis in Iron Pipes. C. HERING. (*Elect. Rly. Journ.*, xlii, 1135.)—It is shown in this article that the interpretation of results obtained by the usual tests for electrolysis on underground metal pipes requires great caution. In a number of cases it is quite easy to draw misleading conclusions unless the conditions are examined with great care. A considerable difference of voltage between adjoining pipes may mean that there is no actual danger, as everything depends on the nature and resistance of the surrounding soil. The so-called "indirect" method, using voltmeter and ammeter, and determining the voltage across the iron pipe both with the ammeter connected and disconnected, is also fallacious; the voltage producing the current may originate at some distant point, and in that case it is easily seen that the resistance of the ammeter itself may seriously affect the figures. Other instances are given where it is shown that the readings, taken by an unskilled observer, are very liable to misinterpretation; and even if this should not be so, there is still to be said that such readings often have no true bearing on the point under examination.

The Testing of Materials. ANON. (*Bur. of Standards, Circ.* 45.)—This circular gives information on the general aspects of the subject valuable to the user or buyer of materials. A brief outline is given with regard to each class of material of the tests usually made, the conditions under which such work is undertaken, and some of the limitations. The classes of materials include metals, cements and concrete, ceramic materials, inks, paper, textiles, rubber, leather, lubricating oils and greases, chemicals and miscellaneous technical materials.

Tobacco Growing in Great Britain. ANON. (*Times*, Aug. 6, 1912.)—The Government has accepted an amendment which exempts from payment of excise duty all tobacco grown in this country by responsible persons under licenses from the Treasury, for the extraction therefrom of nicotine to be used in the preparation of insecticides or otherwise for purely agricultural or horticultural purposes.

Silicon Castings. T. B. ALLEN. (U. S. Pat. 1,073,560.)—Allen purifies the silicon which, made in electric furnaces, contains oxide, oxygen and nitrogen and yields porous castings full of blow-holes, by means of metals which deoxidize and remove nitrogen, such as Ca, Mg, V. The silicon is tapped from an electric furnace into a graphite crucible placed in an oil or coke furnace, in which the silicon is kept fluid for a few hours. From 0.5 to 3 per cent. of Mg is added to the Si in the crucible, until no further reaction is observed. The mould is made of sand and coated with talc. The castings resist acids and are suitable for chemical ware.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE DETERMINATION OF AMMONIA IN ILLUMINATING GAS.

By J. D. Edwards, Bureau of Standards.

THE Bureau of Standards Technologic Paper No. 34 presents the results of a brief investigation of the apparatus and methods employed for the commercial determination of ammonia in illuminating gas. The method generally used for the determination of ammonia in purified illuminating gas depends upon the absorption of the ammonia in a standard acid solution, the amount of ammonia absorbed from a measured volume of gas being determined either by titration of the acid remaining unneutralized or less frequently by allowing the gas to pass until a change is shown by the indicator used.

The choice of the proper indicator to use for this determination is of greater importance than the choice of apparatus. The indicators which were found to be most suitable for the determination of ammonia in gas were sodium alizarinsulphonate, cochineal and paranitrophenol. The presence of glass beads, which are used in some of the absorption apparatus, may lead to erroneous results for two reasons: First, the beads may yield alkali on contact with the absorbing liquid; second, washing of the beads may be incomplete. It is recommended that the operator test the solubility of any beads he may use; the method of washing out the apparatus should also be tested.

Five different forms of apparatus were tested: The Referees apparatus, the Emmerling tower, the Lacy apparatus, the common form of gas wash bottle and a modified form of the Cumming gas bottle. The relative efficiency, and from this the probable accuracy, of the different forms of apparatus were determined by running them in parallel, using gas from a common supply. As a result of this comparison it was found that the Emmerling tower gave results which were somewhat higher than those obtained with the other forms and that the wash bottle gave results

* Communicated by the Bureau.

consistently lower. With careful operation, any one of the five forms of apparatus tested would ordinarily give results that are well within the limits of accuracy required for this determination, either for commercial control work or for the purpose of gas inspection.

ABSTRACT OF THE INFLUENCE OF ATMOSPHERIC CONDITIONS IN THE TESTING OF SUGARS.

By F. J. Bates and F. P. Phelps.

A SIMPLIFIED form of Marvin's evaporation equation has been applied to the evaporation of raw sugar solution during filtration. Marvin's formula reduces to

$$\frac{dq}{dt} = C(P_s - P_a)$$

or $Q = C(P_s - P_a)T$, which, it is shown, fits the observations satisfactorily. Q = the change due to evaporation in the time T; P_s = the vapor pressure of the sugar solution; P_a = the saturation vapor pressure in the air at the temperature of the dewpoint.

The constant, C, has been determined for a number of different cases: First, when the solution is poured back upon the filter after all has run through; second, when it is poured back after about half has run through; third, when it is not poured back at all. Observations were made by two methods: First, by weighing the solution at intervals during the filtration; second, by observing the change in polarization. In the polarization method one tube was filled, as a reference tube, with solution that had been covered during filtration, since filtration could not be avoided. It is shown, however, by weighing, that the evaporation in this case is quite negligible. Other tubes were filled with solution which had not been covered during filtration. The difference in polarization between these tubes and the reference tube is the change due to evaporation. This was done under various atmospheric conditions.

The observations were made in a thermostated room where the amount of moisture present in the air, as well as the temperature, could be varied at will, the range of adjustment being

$(P_s - P_a) = 4$ mm. of Hg to $(P_s - P_a) = 41$ mm. of Hg. In practice $P_s - P_a$ rarely exceeds 22 mm.

It was found that in the case where the solution was not poured back upon the filter the change in polarization due to evaporation is so small as to be quite negligible in ordinary sugar testing. The change is represented by $Q = 0.00017(P_s - P_a)T$. However, in case that even a portion of the solution is poured back the change due to evaporation is not negligible in ordinary testing but must either be prevented or corrected for.

It may be prevented by covering the funnel, or corrected for by the equation $Q = 0.0006(P_s - P_a)T$.

INDUSTRIAL GAS CALORIMETRY.

FOR many years all laws and regulations relating to manufactured gas were based on candle-power requirements, *i.e.*, the gas burned in a definite burner at the rate of 5 cubic feet per hour was required to give a specified illumination of so many candle-power. This specification furnished a perfectly satisfactory control of the quality of gas delivered so long as the gas was chiefly used for illuminating purposes with the old style of open-flame gas burner. At the present time, however, this inefficient type of burner has been very largely displaced by burners of the Welsbach mantle type. Furthermore, a large amount of the gas sold to-day is used for cooking purposes and to some extent for operating small gas engines for power purposes. In these applications of gas it is the heating value that is of first importance and not the candle-power. It has been estimated that less than 20 per cent. of the gas manufactured and sold to-day, indeed in many of our cities and towns less than 10 per cent., is used in the old type of open-flame gas burners. Notwithstanding this fact we still find in most of our cities and towns ordinances on the statute books requiring that the gas meet a definite candle-power test, while no attention has been given to the question of heating value, which is the important factor for over 80 per cent. of the gas sold. Many of the candle-power requirements fixed by law are quite high, often requiring the manufacture of an expensive oil-enriched gas, which may not be the most economical gas to the public. The importance of the heating value of the gas is now being quite generally recognized, and where new legislation

has been adopted recently and where public-service commissions have considered the question of gas regulation and have gotten to the point of issuing regulations, the heating value standard is being generally adopted, supplemented in some cases by a moderate candle-power standard, the latter with a view to affording the necessary protection to those who still use the open-flame burner.

In view of the growing importance of the question of heating values of gases from the manufacturing, the legislative, the inspecting, and the economic sides, the Bureau of Standards, of the Department of Commerce, started several years ago an exhaustive investigation of the instruments widely used in this country and abroad to measure the heating values of gases, with a view to determining the sources of error to which the instruments are liable, the important precautions to be observed in their use, and the accuracy attainable with them. This investigation has now been completed, and the results will be published in a forthcoming technologic paper, reprints of which may be obtained by those interested in the subject by addressing a written request to that bureau. It is expected that the paper will come from the press about June 1.

Experiments on the Efficiency of Rope Driving. H. Bonte. (*Zeitschr. Ver. Deutsch. Ing.*, lvii, 1711.)—Recently many firms have transformed rope-driving into belt-driving systems, largely on account of the insufficiently criticised results of Kammerer. Experiments on a 200 horse-power plant are described. The ropes used for driving purposes are especially flexible. The efficiency of transmission has a mean value of 97.3 per cent. and increases with the load. The author thinks that few ropes are sufficiently stressed in practice. Rope driving properly applied is quite as efficient as leather belting, and probably more efficient than double or triple belts. It occupies less space and the initial cost is less.

Crystallization through Fatigue of Iron and Steel. F. Rogers. (*Iron and Steel Inst.*, Sept., 1913.)—The crystalline structure frequently shown by wrought iron or steel which has given way through repeated stress does not appear to be the result of fatigue, since in every case of such failure coming under the author's notice, a fracture of similar appearance could be obtained in an unfatigued part of the metal. Examples of the failure of wrought iron are given in which such crystalline structures, in both the new and the fatigued metal, were due to the presence of low-grade iron or steel scrap.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, April 15, 1914.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 15, 1914.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 3.

Dr. Allerton S. Cushman, Director, Institute of Industrial Research, Washington, D. C., presented a paper on "Researches in the Metallurgy of Iron." The speaker pointed out the great importance of the problems involved in the production of perfectly sound finished steel and iron. Various methods which have recently been proposed for accomplishing the purpose were reviewed and illustrated, and many of the lecturer's own investigations, as they apply more particularly to the production of very high purity commercial iron, were described for the first time. The bearing of the production of extremely homogeneous metals on the important problems of corrosion was further considered. The subject was illustrated by numerous lantern slides of cross-sections of metals, the various stages of corrosion and of apparatus used in tests and experiments.

After a vote of thanks to the speaker, the meeting adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1913–14.

The number of students enrolled in all Departments of the School this year was 320, an increase of fifteen over the previous year. This enrolment was the largest since the discontinuance in 1899 of the Institute's Branch School at Germantown Junction, which was maintained for several years.

The majority of students registered in one of the four departments of drawing, mathematics, mechanics and naval architecture. Eighteen students were enrolled in two departments, as against sixteen last year.

As heretofore, the largest classes were formed in first-year Mechanical Drawing and Mathematics. Eighty-nine students were admitted to the former of these, and fifty-eight to the latter. There was an exceptionally good representation in all the advanced classes this year; this was particularly the case in the Architectural Drawing and in the Mechanics classes.

Certificates for the satisfactory completion of a two-year course in one

of the four Departments are this year awarded to forty-six students, an increase of two over last year. The good proportion of graduates in Mathematics, Mechanics and Naval Architecture evidenced last year is not only maintained this year, but is bettered; the total number of graduates from these three departments last year was nineteen, while this year it is twenty-two.

On the results of the work of the Winter Term, six students in the Department of Drawing were awarded Scholarships from the B. H. Bartol Fund, entitling them to free tuition in the Spring Term; one student in each of the Departments of Mathematics, Mechanics and Naval Architecture was awarded a Scholarship from the Isaac B. Thorn Fund, entitling him to free tuition in the Spring Term; Certificates of Honorable Mention were also awarded to those students in the respective classes in all Departments who maintained the best attendance and were the most proficient in their work.

On the results of the work of the Spring Term, six students in the Department of Drawing are awarded Bartol Scholarships, and one student in each of the Departments of Mathematics, Mechanics and Naval Architecture is awarded an Isaac B. Thorn Scholarship; these students will be entitled to free tuition during the Winter Term, 1914–15. Certificates of Honorable Mention are also again awarded.

The list of graduates for the season 1913–14, as well as of recipients of the above honors, and of the following special prizes awarded on the results of the year's work, is appended hereto:

Mr. J. B. McCall's Prize for Mathematics.

Mr. Wilfred Lewis's Prize for Mechanics.

The New York Shipbuilding Co.'s Prize for Naval Architecture.

The Alumni Association of The Franklin Institute's Prizes awarded to the most proficient students in each Department.

In conclusion, I desire to express my sincere appreciation of the continued co-operation of Mr. Wm. E. Bullock, Assistant Director, and Messrs. Clement Remington, Frank H. Lobb, I. P. Pedrick, Chas. Rommel, W. W. Twining, H. P. Tyson, Elmer Bark, and H. C. Towle, and of the work of Messrs. John F. Allison and W. A. Van Osten appointed this year.

WM. H. THORNE,
Director.

LIST OF GRADUATES, ETC., 1913–14.

MECHANICAL DRAWING.

James P. Cavanagh
Jonathan Cleaver, Jr.
Raymond J. Davies
James R. Edmiston
Albert Forster
Chester Gable
Leon Liberman
Frank E. McDonnell
George S. Moore
Harry J. Schmidt
Maurice Raymond Shultz
Charles P. Smith
Fred W. Sperling
Arthur L. Stettler
Julius Uhrmann
Arthur Charles Vickery
Harry L. Wells

ARCHITECTURAL DRAWING.

W. Hammond Fletcher
Louis Gorohowsky
Percival Lukens
Rudolph Lukens
Garnier Walz

FREEHAND DRAWING AND WATER COLOR.

William H. Cameron
Walter E. Jones

MATHEMATICS.

Harry H. Bonner
James P. Cavanagh
Benjamin Cheesman
H. Arthur Grosscup
Harry G. Lloyd
John D. Masterson
Walter Merkh
Edward J. Moran
Ellwood A. Smith
Joseph E. Walters

MECHANICS.

Harry W. Barnhurst
William D. Eastwood
George M. Harrison
William M. Meinel
J. F. Pfeffer
Arnold Rogers

NAVAL ARCHITECTURE.

James S. Bowen
Thomas Devine
S. W. Garrigues
Willis M. Hayden
Einar Jentoft
William E. Taylor

BARTOL SCHOLARSHIPS.

WINTER TERM.

Wm. Henry Clarke
Harry Haering
Benjamin Lamb
Frank Long
Warren G. Tilton
Alfred G. Windstein

SPRING TERM.

Gordon N. Davis
Louis Gorohowsky
Howard A. Graul
Harry Haering
Welling G. Schrack
Fred Stadtler

ISAAC B. THORN SCHOLARSHIPS.

WINTER TERM.

Emil C. Schneider
James G. Morgan
Thomas Devine

SPRING TERM.

John G. Merkh
Harry N. Rahn
Thomas Devine

MR. J. B. MCCALL'S PRIZE.

MATHEMATICS.

Ellwood A. Smith

MR. WILFRED LEWIS'S PRIZE.

MECHANICS.

William M. Meinel

THE NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Lawrence Hoban

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE.

GRADUATES AWARDED PRIZES BY THE ASSOCIATION.

Raymond J. Davies,
Mechanical Drawing

Louis Gorohowsky,
Architectural Drawing

Walter E. Jones,
Freehand Drawing

Edward J. Moran,
Mathematics

George M. Harrison,
Mechanics

William E. Taylor,
Naval Architecture

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, April 1, 1914.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 1, 1914.

MR. J. A. P. CRISFIELD *in the Chair.*

The following reports were presented for final action:

No. 2541.—Guillaume's Alloy "Invar." John Scott Legacy Medal and Premium. Recommendation adopted.

No. 2596.—Hirsch's Electric Safety Lamp. Edward Longstreth Medal of Merit. Adopted.

The following reports were presented for first reading:

No. 2585.—Ridgway's Steam-Hydraulic Elevator.

No. 2589.—Nitrogen-Filled Tungsten Lamps. Recommendation Deferred. Advisory. Adopted.

The following application for investigation was accepted:

No. 2605.—Blonck Efficiency Meter.

The following subject was recommended for examination:

No. 2506.—John W. Hyatt's Researches Leading to the Establishment of the Nitrocellulose Industry.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A joint meeting of the section and of the Aero Club of Pennsylvania was held in the Hall of the Institute on Thursday evening, March 26, 1914, at eight o'clock.

Dr. Walton Clark, President of the Institute, and Mr. Clarence P. Wynne, President of the Aero Club, presided jointly.

The minutes of the previous meeting were approved as published.

Dr. Clark introduced Lieut.-Colonel Samuel Reber, U. S. A., in charge of the aeronautical work of the Signal Corps, who delivered a lecture entitled "Recent Progress in Military Aeronautics." By means of numerous lantern slides of the latest types of dirigibles and aeroplanes, the lecturer illustrated the present aeronautical equipment of the troops of the principal nations. He developed the necessity and importance of a suitable air force in war, and gave instances of the utility of such a force in northern Africa and in the recent war in the Balkans. He spoke of the backwardness of the United States in military aeronautics, attributing this to a lack of interest both on the part of Congress and of the people at large. He urged an awakening of the popular interest in what should, he thought, be one of our principal means of defense.

The remarks of the speaker were discussed by several members present, and the thanks of the meeting were then extended to Colonel Reber.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, April 2, 1914, at eight o'clock.

Mr. G. R. Henderson, President of the section, presided.

The minutes of the previous meeting were approved as published.

The chairman introduced Mr. John A. Vogleson, President of the Board of Health and Chief of the Bureau of Health of the City of Philadelphia, Member of the Institute, who delivered a lecture entitled "Some Engineering Problems in Sanitary Science," in which he demonstrated what has been done to promote sanitary conditions with the object of reducing communicable diseases in the city of Philadelphia.

The lecture was illustrated by means of lantern slides. After discussion by members present, the thanks of the meeting were extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A meeting of the section and the Illuminating Engineering Society was held in the Hall of the Institute on Thursday evening, April 9, 1914, at 8 oclock.

Dr. George A. Hoadley occupied the chair.

The minutes of the previous meeting were approved as published.

The chairman introduced Mr. Preston S. Millar, of the Electrical Testing Laboratories, New York City, who delivered a lecture entitled "Recent Developments in the Art of Illumination." In his lecture, the speaker indicated the efforts made in the last few years to improve artificial lighting and described the present status of pending developments in the illuminating art.

The speaker's remarks were discussed by members present, and the thanks of the meeting were then extended to the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

(*Stated Meeting, Board of Managers, March 11, 1914.*)

RESIDENT.

MR. S. PEACOCK, 5911 Washington Avenue, Philadelphia.
MR. ARTHUR J. RHOADES, Pennsylvania Salt Works, Philadelphia.

NON-RESIDENT.

MR. ELWOOD GRISSINGER, 924 White Building, Buffalo, New York.

Changes of Address.

MR. A. B. BEADLE, New Hartford, Connecticut.
MR. A. S. KREBS, 115 Ridgewood Road, Ithaca, New York.
MR. ISHAM RANDOLPH, 1827 Continental and Commercial National Bank Building, Chicago, Illinois.
MR. V. A. SUYDAM, University of Mexico, Albuquerque, Mexico.

NECROLOGY.

Mr. Charles W. Close, Philadelphia.
Mr. George E. Kirkpatrick, Philadelphia.

LIBRARY NOTES.

Purchases.

ALLEN, H. S.—Photo-electricity, Liberations of Electrons by Light. 1913.
American Electrochemical Society.—Transactions, vol. 24. 1913.
BEIN, W.—Comp. Otto v. Guericke, ueber die luft pumpe und den luft druck. 1912.

Engineering Index.—Annual 1913. 30th year.
HENRIET, E.—Manuel pratique de surrurerie. 1914.
Hero of Alexandria, Works.—5 vols. 1899–1912.
HISCOX, G. D.—Henley's Twentieth Century Formulas, Receipts. 1914.
International Congress for Testing Materials. Proceedings of 6th Congress. 1912. 2 v.
KONEN, HEINRICH.—Das Leuchten der Gase und Dämpfe. 1913.
LONES, T. E.—Aristotle's Researches in Natural Science. 1912.
MACKENZIE, J. E.—The Sugars and Their Simple Derivatives. 1914.
MOUREAU, CHARLES.—Notions fondamentales de chimie organique. 1913.
OSTWALD, WILHELM.—Werdegang einer Wissenschaft. 1908.
OWEN, DAVID.—Recent Physical Research. 1913.
PAINE, P. M., and STROUD, B. K.—Oil Production Methods. 1913.
PERRIN, JEAN.—Des atomes. 1913.
PHILLIPS, FRANCIS C.—Chemical German. 1913.
SHEPPARD, S. E.—Photo-chemistry. 1914.
SMITH, ERNEST A.—Sampling and Assay of the Precious Metals. 1913.
STANFIELD, ALFRED.—The Electric Furnace. 1914.
Taschenbuch der Luft flotten. 1914.
Thomas' Register of American Manufactures. Sixth ed. 1914.
THOMSON, SIR J. J.—Rays of Positive Electricity, and Application to Chemical Analysis. 1913.
TILDEN, SIR W. A.—Progress of Scientific Chemistry in Our Own Times. 1913.
WELLS, M. B.—Steel Bridge Designing. 1913.

Gifts.

Alabama Geological Survey, Bulletins 13 and 14 and Monograph 8. University, 1913. (From the Survey.)
All About Colorado. Denver, Colo., 1913. (From Mr. L. C. Phipps.)
Bureau for the Safe Transportation of Explosives. Report of the Chief Inspector, 1914. New York, 1914. (From the Chief Inspector.)
Canada Department of Mines, Annual Report on the Mineral Production of Canada, 1912. Geological Survey. Guide Books, Nos. 5, 8; pts. 1–3; 9, 10. Ottawa, 1914. (From the Department.)
Canada Department of Trade and Commerce, Report, 1913, pt. 1. Ottawa, 1914. (From the Department.)
Central University of Kentucky, Catalogue of the Central College, 1913–1914. Danville, 1914. (From the University.)
Danish Beer and Continental Beer Gardens, by Dr. Max Henius. New York, 1914. (From the United States Brewers' Association.)
Fairmount Park Art Association, 42nd Annual Report. Philadelphia, 1914. (From the Association.)
General Society of Mechanics and Tradesmen, 124th Annual Report, 1913. New York, 1914. (From the Society.)
Georgetown University, Catalogue 1913–1914. Washington, D. C., 1913. (From the University.)

Hobart College, Catalogue 1913–1914. The Installation of Lyman Pierson Powell as President; November 14, 1913. Geneva, N. Y., 1914. (From the College.)

Institution of Engineers and Shipbuilders in Scotland, Transactions, vol. 56. Glasgow, 1913. (From the Institution.)

Medford Water and Sewer Commissioners, Annual Report, 1913. Medford, Mass., 1914. (From the Commissioners.)

Metropolitan Sewerage Commission, Preliminary Reports on the Disposal of New York's Sewage, Nos. 11–16. New York City, 1914. (From the Commission.)

Michigan Agricultural Experiment Station, 26th Annual Report. Lansing, 1913. (From the Station.)

Michigan State Public Domain Commission, Report, January, 1911–June, 1913. Lansing, 1914. (From the Commission.)

Missouri Bureau of Geology and Mines, vol. 12 (second series); The Geology of the Rolla Quadrangle. Jefferson City, n. d. (From the Bureau.)

Mysore Meteorological Department, Report on Rain Fall Registration in Mysore, 1912. Bangalore, 1914. (From the Department.)

North Dakota Geological Survey, Sixth Biennial Report. Bismarck, 1912. (From the Survey.)

Nova Scotia Department of Mines, Report, 1913. Halifax, 1913. (From the Department.)

Ontario Department of Agriculture, Vegetable Growers' Association, 9th Annual Report, 1913. Agricultural Societies, Appendix to Annual Report, 1913. Toronto, 1914. (From the Department.)

Pennsylvania Board of Commissioners of Public Charities, 43rd Annual Report, 1912; Factory Inspector, 23rd Annual Report, 1912; Forty-seventh Annual Encampment of the Grand Army of the Republic, 1913; Smull's Legislative Hand-Book, 1913. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Prison Society, The Journal of Discipline, March, 1914. Philadelphia, 1914. (From the Society.)

Piano and Organ Purchaser's Guide for 1914. New York City, 1914. (From The Music Trades Co.)

Pittsburgh, Cincinnati, Chicago & St. Louis Railway Co., 24th Annual Report, 1913. Pittsburgh, 1914. (From the Company.)

Pittsburgh Flood Commission, Report, 1911. 2 vols., N. p., n. d. (From Mr. John Birkinbine.)

R. Accademia Delle Scienze Dell'Instituto Di Bologna. Memorie, Tomo 9, pts. 1–4. Rendiconto, vol. 16. Bologna, 1912. (From the Institute.)

Rose Polytechnic Institute, 32nd Annual Catalogue. Terre Haute, Ind., 1914. (From the Institute.)

Royal Philosophical Society of Glasgow, Proceedings, vol. 44. Glasgow, 1913. (From the Society.)

Syracuse University, Catalogue, March, 1914. Syracuse, N. Y., 1914. (From the University.)

Taunton Water Board, Report for 1913. Taunton, Mass., 1914. (From the Board.)

University of Toronto, Calendar, Faculty of Applied Science and Engineering, 1914–1915. Toronto, Can., n. d. (From the University.)

University of Vermont, Catalogue, 1913–1914. Burlington, 1914. (From the University.)

Ursinus College, Catalogue, 1913–1914. Collegeville, Pa., 1914. (From the College.)

Washington Public Service Commission, 3rd Annual Report. Olympia, 1913. (From the Commission.)

PUBLICATIONS RECEIVED.

Karbide und Silizide, von Prof. Dr. Otto Hönigschmid. 263 pages, illustrations, 8vo. Halle (Saale), Wilhelm Knapp, 1914. Price, in paper, 18.60 marks.

A Laboratory Guide to the Study of Qualitative Analysis Based upon the Application of the Theory of Electrolytic Dissociation and the Law of Mass Action, by E. H. S. Bailey, Ph.D., and Hamilton P. Cady, Ph.D. Seventh edition, 280 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1914. Price, $1.25.

Animal Flight. A record of observation, by E. H. Hankin, M.A., Sc.D. 412 pages, illustrations, 8vo. London, Iliffe & Sons, 1913. Price, 12 shillings and 6 pence.

Designing and Detailing of Simple Steel Structures, by Clyde T. Morris, C.E. Third edition, revised and reset. New York, McGraw-Hill Book Co., 1914. Price, in cloth, $2.25.

U. S. Bureau of Standards, Scientific Paper No. 213. Critical Ranges A_2 and A_3 of Pure Iron, by G. K. Burgess and J. J. Crowe. (Reprinted from Bulletin of Bureau of Standards, vol. 10.) 53 pages, plates, 8vo. Washington, Government Printing Office, 1914.

Canada Department of Mines, Mines Branch. Researches on Cobalt and Cobalt Alloys, Conducted at Queen's University, Kingston, Ontario. Part I. Preparation of Metallic Cobalt by Reduction of the Oxide, by H. T. Kalmus, B.Sc., Ph.D., assisted by C. W. Day, M.A., C. Harper, B.A., W. L. Savell, B.Sc., and R. Wilcox. 36 pages, illustrations, plates, 8vo. Ottawa, Government Printing Office, 1913.

Philadelphia, Department of City Transit, Rapid Transit Development with Universal Free Transfers. Reply of the Department of City Transit to Proposals of March 25, 1914, by the Philadelphia Rapid Transit Compny. 22 pages, 8vo. Philadelphia, April 7, 1914.

U. S. Bureau of the Census, Forest Products: Lumber, Lath, and Shingles, 1912. Compiled in Coöperation with the Department of Agriculture Forest Service, Henry S. Graves, Forester. 60 pages, 8vo. Washington, Government Printing Office, 1914.

The Postalization of the Telephone and the Telegraph, Speech of Hon. David J. Lewis, of Maryland, in the House of Representatives, January 16, 1914. 15 pages, 8vo. Washington, 1914.

U. S. Department of Agriculture, Bulletin No. 55, Professional Paper,

Balsam Fir, by Raphael Zon, Chief of Forest Investigations. 68 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1914. Price, ten cents.

U. S. Coast and Geodetic Survey. Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1911 and 1912, by Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 100 pages, tables, plates, 4to.

Terrestrial Magnetism. Results of Magnetic Observations Made by the United States Coast and Geodetic Survey between July 1, 1911, and December 31, 1912, by R. L. Faris, Inspector of Magnetic Work; Assistant, Coast and Geodetic Survey. Special Publication No. 15, Washington, Government Printing Office, 1913 and 1914.

U. S. Bureau of Mines, Bulletin No. 42. The Sampling and Examination of Mine Gases and Natural Gas, by George A. Burrell and Frank M. Seibert. 116 pages, illustrations, 8vo. Bulletin 68, Electric Switches for Use in Gaseous Mines, by H. H. Clark and R. W. Crocker. 38 pages, plates, 8vo. Technical Paper No. 57, Petroleum Technology 13, a Preliminary Report on the Utilization of Petroleum and Natural Gas in Wyoming, by W. R. Calvert, with a discussion of the Suitability of Natural Gas for Making Gasoline, by George A. Burrell. 23 pages, 8vo. Technical Paper No. 69, Production of Explosives in the United States During the Calendar Year 1912, compiled by Albert H. Fay. 7 pages, 8vo. Technical Paper No. 71, Permissible Explosives Tested Prior to January 1, 1914, by Clarence Hall. 12 pages, 8vo. Washington, Government Printing Office, 1913–1914.

Scanes' Vacuum Efficiency and Absolute Pressure Gauge. A. E. L. SCANES. (*Mech. Eng.,* xxxii, 457.)—The principle of this efficiency gauge is that for a given water temperature there is an absolute vapor pressure. If a glass U-tube, sealed at one end, is exhausted of air and partially filled with water, heated to the temperature of the condenser circulating discharge, then on connecting the open end to the condenser vacuum the water in the U-tube will show, by the difference of levels, a measure of the "condenser" efficiency. A similar arrangement heating the water-tube to condensed steam temperature will represent "vacuum" efficiency. The former of these indications will vary with the condition of the condenser tubes, and the latter with the proportion of air not removed by the air-pump. Should the vacuum decrease while both efficiencies are normal the cause can only be too little circulating water, or its too high temperature. The instrument devised by the author with an improved absolute pressure gauge is described and illustrated.

CURRENT TOPICS

Inflammability of Coal Dust. J. C. W. Frazer, E. J. Hoffman and L. A. Scholl, Jr. (*Bureau of Mines,* Bull. 50, 1913.)—The dust is exploded in a spherical bulb of 1.6 litres capacity provided with two tubular necks. The one above is closed by a brass plate, into which a brass tube, 7 mm. diameter, is soldered, rising vertically; on top of this tube rests a vessel charged with mercury; this vessel (or pressure valve) is raised by the explosion pressure, which can be determined within 5 grammes by a few experiments. The coal dust is blown into the bulb through a tube, opening out into a funnel, which passes through the lower neck. Ignition is effected by a coil of platinum wire suspended in the vessel. The pressure valve is opened at intervals of 1, 2 and 2¾ minutes after closing the circuit in order to let the warm air escape, and the charge of 0.05 gramme of coal dust is blown into the bulb at the end of the third minute. Many samples of coal from different mines and of coal dusts from mine roads were tested in this way; also coal dusts mixed with stone dusts and other dusts. The many curves reproduced plot the pressure (in grammes for the tube of 7 mm.) against the current intensities which ranged from 5 to 7 ampères. With pure coal the pressure rose in most cases to 250 grammes, either steadily, or slowly at first and then rapidly to something like a maximum. The addition of stone dust (shale or calcium carbonate) lowered the pressure; but 10 or even 20 per cent. of stone dust had little effect in this respect, and ignition always occurred with the maximum percentage (50) of stone dust used. The other materials tested were various woods (pine, oak, mahogany), asphalt, sugar and lycopodium. Analyses of the coals, stating the moisture, volatile matter, fixed carbon, ash and sulphur, are given.

Danger Signals at Grade Crossings. Anon. (*Sci. Amer.*, cix, No. 22, 407.)—The Lehigh Valley Railroad is installing, at highway grade crossings, danger signals which should prove to be very effective. As soon as a train comes within a mile of a crossing, the signal shows a red light and a gong which can be heard 500 yards away begins to ring. Both warnings continue to act until the train has passed, when the gong ceases and the red light changes to white. If the wires become deranged, or should anything happen to the mechanism, the signal on the disc flashes to danger and remains there till repairs are made. Nothing short of demolition can prevent the signal from working.

Nitrate Industry of Chile. ANON. (*Oil, Paint and Drug Reporter,* Dec. 8, 1913.)—According to the annual report of the Nitrate Propaganda Association, the total production of sodium nitrate in Chile during 1912 was 2,885,959 short tons, as compared with 2,784,361 tons in 1911. Exports from the whole district in 1912 were 2,753,500 tons as compared with 2,705,382 tons in 1911, 2,579,945 tons in 1910, and 2,357,968 tons in 1909. During last year the United States received about 500,000 tons of the product. Germany received about 600,000 tons, and the United Kingdom 1,000,000 tons out of the total listed exports. Of iodine the United States took 183 tons, as against 264 tons to European countries and 65 tons to the United Kingdom. Considerable progress has been made in the use of oil as fuel for boilers in the oficinas, and it is said to effect a saving of about 40 per cent. It is proposed to carry out experiments on a large scale, with a view to discover a method of treating low-grade caliche.

Feed Water Heating. ANON. (*Sci. Amer.,* cix, No. 24, 451.)—The new Brooke high velocity feed water heaters are said to deliver water 20 degrees hotter than the usual heaters and save considerable fuel. When working with exhaust steam it is known that heaters rarely deliver water hotter than 170° to 180° F. when working at maximum capacity. With the new system the temperature reaches 200° F. Such heaters are made in vertical and horizontal types and work equally well on live and exhaust steam, a very economical arrangement being to have an exhaust and live steam heater working in conjunction.

Production of Pyrite and Sulphuric Acid in 1913.—The production of pyrite in the United States in 1913, according to W. C. Phalen, of the United States Geological Survey, was 341,338 long tons, valued at $1,286,084. For 1912 the output amounted to 350,928 long tons, valued at $1,334,259, a decrease for 1913 in quantity of 9590 long tons and in value of $48,175. The production in the leading States—Virginia and New York—diminished slightly, in California there was an increased production, and in Wisconsin the output also continued to increase. The output of by-product pyrite, obtained in connection with coal mining, fell off materially.

Imports of Pyrite.—The imports of pyrite for consumption during the calendar year 1913 were 850,592 long tons, valued at $3,611,137. These figures show a notable decrease in quantity of 120,193 long tons, and in value of $230,546, as compared with the imports in 1912, which amounted to 970,785 long tons, valued at $3,841,683.

Production of Sulphuric Acid.—According to actual returns for the year 1913 the production of sulphuric acid in the United States was 3,538,980 short tons of 50° acid, valued at $22,366,482. This output does not include a small amount of fuming acid, but does

include by-product acid—that is, acid obtained in the smelter industry. The acid produced at copper and zinc smelters in 1913 amounted to 790,296 short tons of 50° acid, valued at $4,346,272. The production of acid by grades is tabulated in detail below:

PRODUCTION OF SULPHURIC ACID IN THE UNITED STATES IN 1913, BY GRADES, IN SHORT TONS.

Grade.	*Quantity.*	*Value.*	*Price per ton.*
50° Baumé	1,643,318	$9,212,917	$5.61
60° Baumé	509,929	3,202,528	6.28
66° Baumé	797,104	9,282,422	11.65
Other grades	63,158	986,659	15.62
Total	3,013,509	$22,684,526	$7.53
Total reduced to 50° Baumé acid[1]	3,538,980	$22,366,482	$6.32

PRODUCTION OF SULPHURIC ACID FROM COPPER AND ZINC SMELTERS IN 1911, 1912 AND 1913, IN SHORT TONS (60° Baumé Acid).[2]

Source.	1911.			1912.			1913.		
	Quantity.	Value.	Price per ton.	Quantity.	Value.	Price per ton.	Quantity.	Value.	Price per ton.
Copper smelters	207,657	$1,056,185	$5.09	321,156[3]	$1,985,704[3]	$6.18[3]	336,019	$2,205,627	$6.56
Zinc smelters	230,643	1,677,511	7.27	292,917[3]	2,255,237[3]	7.70[3]	296,218	2,140,645	7.23
Total	438,300	2,733,696	6.24	614,073[3]	4,240,941[3]	6.91[3]	632,237	4,346,272	6.78
Total acid reduced to 50° Baumé	547,875			764,237[4]			790,296		

The year 1913 is the third for which the Survey has collected statistical information on the sulphuric acid industry in the United States. The Survey's figures are not estimates but are compiled from first-hand information received from the producers themselves and cannot exceed actual production.

The above figures are final, so far as the Survey's present information goes, but they are subject to change if necessary when the printed report is issued. The changes, if any are made, will probably be slight.

[1] Exclusive of a small amount of fuming acid.

[2] The acid reported to the Survey includes that of strength of 50°, 53°, 60°, and 66° Baumé, and a small quantity of electrolyte and oleum. All strengths, with the exception of the electrolyte, have been reduced to both 50° and 60° Baumé, as given in the table.

[3] Inclusive of a small quantity of electrolyte.

[4] Exclusive of a small quantity of electrolyte.

Production and Use of Denatured Alcohol in Principal Countries.—Germany now uses between forty and fifty million gallons of denatured alcohol a year, of which over thirty million gallons are sold to the general public for burning purposes. The importance of this fuel in Germany may be appreciated when it is considered that France uses about eighteen million gallons, the United States about ten million gallons, and the United Kingdom only four million gallons, according to a monograph by Charles A. Crampton, commercial agent of the Department of Commerce, recently issued by the Bureau of Foreign and Domestic Commerce. Denatured alcohol is not only gaining in favor for general burning purposes, but a determined effort is being made to find a way of using it as a motor fuel in place of a high-priced gasoline. All the recent developments are dealt with in the new monograph, which is entitled "Production and Use of Denatured Alcohol in Principal Countries" (Special Agents' Series, No. 77). Copies at five cents each may be had from the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Propagation of Electric Waves.—The effect of solar eclipses on the propagation of electric waves will be investigated by the British Association for the Advancement of Science during the total eclipse of the sun which will take place August 21, 1914. It was observed during the solar eclipse of April 17, 1912, that the strength of wireless signals was greater during the eclipse than an hour before or after. To investigate the propagation of signals across the umbra, it will be necessary to arrange for wireless telegraph stations on either side of the central line of the eclipse to transmit signals at intervals while the umbra passes between them. This transit of the umbra occupies about two minutes, therefore it is very desirable that the Scandinavian and Russian stations should transmit frequently throughout several minutes before, during, and after totality. The eclipse will be total along a strip extending from Greenland across Norway, Sweden, Russia and Persia to the mouth of the Indus. The Committee of Radiotelegraphic Investigation of the British Association have arranged with wireless stations all over the world for exchange and observation of signals during the eclipse.

Active Nitrogen. E. TIEDE and E. DOMCKE. (*Ber.*, xlvi, 4095.)—Further experiments have confirmed the view expressed previously, that the yellow after-glow considered by Strutt to mark the re-formation of ordinary nitrogen from an active modification produced by the action of electric discharges, is due to the presence of a small quantity of oxygen, and indeed forms an exceedingly sensitive test for the presence of traces of oxygen in nitrogen. An apparatus is described in which pure nitrogen can be generated by heating barium azide in a vacuum and then it is subjected to the electric discharge.

Bureau of Standards' Analyzed Samples.—The Bureau of Standards is prepared to issue purified dextrose as a standard reducing sugar. The substance is free from ash and contains less than 0.1 per cent. of moisture. In an atmosphere of average humidity it is slightly hygroscopic, but if dried at 70° C. it retains less than 0.1 per cent. of moisture. A certificate of analysis showing the quantity of remaining impurity accompanies the sample. The purpose of the standard is to assist in the unification of reducing sugar analysis by supplementing or replacing the use of invert sugar. It is also available for general sugar work.

The fee, payable in advance, is $2 for 70 grams or $3 for 140 grams.

Further information may be obtained in Circular 25 on Standard Samples or Circular 44 on Polarimetry.

Electrolysis of Buried Lead and Iron. GIROUSSE. (*Comptes Rendus,* clvii, 705.)—With a view to suppressing wandering currents capable of attacking water or gas pipes or cable sheathings, the voltage drop in tram rails is limited, in France, to 1 volt per kilometre. It is suggested that what should be specified is the potential difference between rails and metal liable to electrolytic attack. To determine what was the critical potential difference below which attack could not occur, experiments were made with soil taken, (*A*) from a place remote from electric tram lines, (*B*) from a place where serious electrolytic damage had occurred. The samples contained siliceous sand, a high percentage of aluminum silicate and calcium carbonate, with appreciable amounts of calcium sulphate and nitrate and sodium chloride. Loss of weight on incineration, 16 per cent. in case of (*A*); 22 per cent. in case of (*B*). Electrodes of iron and lead (1 mm. thick, 1 sq. dm. area) were placed at opposite sides of boxes containing about 1 cubic dm. of the soils investigated; all the negative and half the positive electrodes were of iron; the remaining positives were lead. Potential differences of 0.1, 0.2 up to 1.0 volt were established between the electrodes in various troughs, and control troughs were arranged to make possible allowance for simple chemical attack. About 20 grammes of water were added daily to each trough, corresponding to 70 cm. annual rainfall; temperature was maintained at about 16° C. The resistance of dry soil was found to be almost infinite, but that of very moist soil fell to 10^3 ohms/cm.; after watering for some weeks, the resistance fell to 600 ohms/cm. at the moment of applying potential difference, and to 2500 ohms/cm. after several months' electrolysis. The contact resistance between electrodes and the earth varied inversely with the surface area, and lead offered a much higher contact resistance than iron; between iron = iron 11 times as much current flowed as between lead = iron. Soil and contact resistance were independent of electromotive force and current density within the limits of the tests (16 volts and 0.01 amp./dm.^{2}). Between lead and iron on

open circuit there was a potential difference of 0.15 to 0.2 volt from lead to iron. When current flowed through the test troughs, lead nitrate and carbonate formed on the lead; the iron plates were attacked much more vigorously, and ferric hydrate with traces of ferrous oxide was found in the surrounding soil. The composition of the soil had an important bearing on the loss of weight per ampère-hour in cases (*A*) and (*B*) respectively; approximate data are 1.6 grammes and 2.88 grammes lead, and 1.33 grammes and 0.89 gramme iron per ampère-hour. The conclusion reached is that iron pipes are attacked electrolytically if they are positive to return rails; before lead is thus attacked, a critical potential difference of 0.2 volt must be exceeded; in any particular case, lead is attacked much less readily than iron.

The Toxic and Antiseptic Properties of Paints.—At the Thirtieth Annual Convention of the International Association of Master House Painters and Decorators of the United States and Canada, Mr. Henry A. Gardner, Assistant Director of The Institute of Industrial Research, Washington, D. C., read a paper on The Toxic Effect of Pigments. The paper included chapters on the Composition and Toxicity of Oil Paint Vapors; Cause and Prevention of Toxic Effect of Pigments; and The Relative Toxicity of Volatile Thinners. The Summary of Conclusions was as follows:

Lead poisoning may occur through the inhalation of the dust from dry lead pigments, or by the careless handling and hand-mixing of lead paints. It may be prevented by establishing more cleanly and sanitary working conditions, through observance of the rules of personal hygiene, and by the adoption and use of prepared paint products.

Drying oil paints do not evolve metallic vapors. They do, however, give forth small quantities of carbon monoxide gas. Paints also emit in vaporous form the volatile products used as thinners. Of these products, benzol is most dangerous, while high boiling-point petroleum spirit is least harmful. With proper ventilation the fumes from drying paints are diluted and dissipated by the atmosphere so that they become harmless.

Drying oil paints evolve aldehydes and other germicidal substances in vaporous form. The antiseptic effect of such vapors is pronounced. The application of oil paints is therefore to be considered as one of the most efficient means of rendering living and sleeping rooms thoroughly sanitary.

CORRECTION.

"The Present Physical Knowledge of X-Rays," by Wheeler P. Davey, March, 1914, page 293.

Reference No. 6, page 294, should read: [6] J. de Beaujeu, Arch. d'Elect. Med., May 25, 1910.

The Future of Oil Fuel. B. REDWOOD. (*J. Roy. Soc. Arts*, lxii, 103.)—The world's output of petroleum has increased from 22,000,000 metric tons in 1901 to 46,500,000 metric tons in 1911, or from 2.8 to 4.3 per cent. of the world's output of coal. The United States supplies about 63 per cent. and Russia about 19 per cent. of the total output, the remaining 18 per cent. is supplied by Mexico, Roumania, Dutch East Indies, Galicia, India, and about 1½ per cent. from other countries. The demand is increasing more rapidly than the supply, and the course of future developments depends on the extent to which supplies can be increased, and also upon the way in which the oil is used. The supply from Russia is likely to increase, as there are large areas still undeveloped. The supply from Mexico will become much greater, but it may be entirely absorbed by the United States. There has been a great increase of production in California, which State is being rapidly transformed from an agricultural to a manufacturing country. Increased supplies may be expected from the Dutch East Indies, Roumania, Peru, Alberta, Persia and Trinidad. Oil fuel is at present used as motor spirit, in place of coal for raising steam, and in Diesel and semi-Diesel engines. The increasing demand is most marked in the case of motor spirit, and methods of increasing the yield of petrol, of obtaining motor spirit from coal tar and from shale oil, and the use of alcohol in place of petrol are discussed. The consumption of petroleum for naval purposes is rapidly increasing, the oil being used for raising steam and for driving Diesel engines. All new warships for the United States Navy are designed for oil-fuel, and an area of about 100 square miles of oil-bearing land in California has been set aside as a reserve supply. Large quantities of oil-fuel are used on locomotives on the Russian State Railways, and the advantages are such that oil would be largely used in Great Britain if adequate supplies could be obtained at a moderate price. In view of the limited supplies, the principal development in the near future, apart from naval requirements, will be in the use of Diesel and semi-Diesel engines, since the high thermal efficiency of these engines makes it profitable to use oil-fuel at a price which would be prohibitive for steam raising. If the market value of oil-fuel becomes established on this basis, it will not be possible to use oil to any great extent in place of coal for raising steam.

Fluorspar in Glass. L. SPRINGER. (*Sprechsaal*, xlvii, 4, 21.)—The use of fluorspar in glass is not recommended except in special cases and under favorable circumstances. It attacks the hearth and walls of the furnace and makes the exit gases more injurious. By the formation and decomposition of silicon fluoride it produces a scum of silica on the surface of the glass, and alters the constitution of the glass in respect of the proportion of acid to base. On the other hand, it is said to impart brilliancy to bottle glass, and to increase its resistance under pressure.

Alloys of Cerium with Silicon and Bismuth. R. VOGEL. (*Z. Anorg. Chem.*, lxxxiv, 323.)—Much heat is evolved in the production of the alloys of cerium with both silicon and bismuth, and the reactive nature of the fused products has rendered thermal investigation difficult. Cerium and silicon form at least one compound, probably of the formula CeSi, and a eutectic containing 47 per cent. Si with a melting point of 1240° C. The alloys are hard and brittle, and stable in the air. At very high temperatures cerium, like magnesium, attacks silica and porcelain. Cerium forms with bismuth the compounds $BiCe_3$, Bi_3Ce_4, BiCe, and Bi_2Ce, the melting points of which, like those of cerium-aluminum compounds, are remarkably high, that of the compound, Bi_3Ce_4, being approximately 1630° C. The bismuth alloys slowly swell up and disintegrate in air, moisture accelerating oxidation, especially with those containing 25 to 75 per cent. of bismuth, which may become heated to visible combustion; dilute acids attack the alloys readily. Hardness reaches a maximum with the compound Bi_3Ce_4, for which it is between 5 and 6 on Mohs' scale.

Use of Pulverized Coal in Metallurgical Furnaces. J. LORD. (*Proc. Eng. Soc. of W. Pennsylvania*, xxix, 363.)—The coal (slack) used for puddling-, heating-, and other furnaces at the works of the American Iron and Steel Manufacturing Company, Lebanon, Pa., contains 1.1 per cent. of moisture, 33.2 of volatile matter, and 9.6 of ash. After drying, it is ground in horizontal (tube) or upright mills until 95 per cent. will pass through a sieve of 100 meshes per square inch (over 80 per cent. of the product will pass a sieve of 200 meshes per square inch) and conveyed through pipes to the storage tanks of the respective furnaces, to which it is subsequently delivered at a uniform rate, and under an air pressure of about one-sixteenth pound per square inch at the furnace mouth, by means of an adjustable "burner" of the screw-conveyer type; a low air-pressure is used to minimize the destructive effects of the projected fuel upon the interior of the furnace. The coal should contain at least 30 per cent. of volatile matter, and not more than 0.5 per cent. of moisture nor 1 per cent. of sulphur; the bulk of the ash is either deposited at the bases of the stacks or collected in the stacks by the aid of suction fans; the furnace charges are not adversely affected by the small amounts of ash which settle upon them. The average cost of preparing and delivering the fuel to the furnaces did not exceed 50 cents per ton of pulverized coal produced in 1912. In four furnaces employed for the production of high-grade puddled bar from gray forge pig iron, the maximum and minimum consumptions of pulverized coal per ton of puddled bar were, respectively, 1472 and 1169 lbs. over a period of two months; during the same period, the maximum and minimum amounts of fuel required for heating iron for rolling were 570 and 516 lbs., respectively, per gross ton of rolled bars. W. A. Evans stated that danger arising

from explosion or the spontaneous combustion of dry, powdered coal could be avoided by keeping the material in motion and not allowing it to remain in the storage-bins for longer than a week. Owing to the volume of flame produced, furnaces for pulverized coal require about four times as much combustion space as ordinary grate furnaces, and they should be entirely free from metallic cooling surfaces. Ash trouble may be minimized by the use of high-grade coal, by employing a bed of cinders in the combustion chamber, and by regulating the temperature of the flues to prevent deposition of slag. The use of powdered coal is stated to be more economical than that of producer gas or oil to the extent of about 25 per cent. in the former and probably much more in the latter case.

Incandescence Mantles, Rare Earths, and their Radio-active By-products. E. STERN. (*Z. Angew. Chem.*, xxvi, 806.)—Incandescence mantles are composed of 97 to 99 per cent. of thorium oxide, 0.8 to 2.8 of cerium oxide and a few tenths of a per cent. of beryllium and aluminum oxides. The higher proportion of ceria is used for mantles for high-pressure gas burners. The traces of the other oxides mentioned impart strength by producing a partial sintering of the deposit. The mechanical distribution of the deposit, or surface development, is determined by the textile thread used. Cotton, with short but fine fibres, gives a very porous but weak mantle, also liable to distortions due to sintering; ramie is much longer and coarser and gives a strong mantle with sufficiently developed surface more stable in the flame; the continuous filament of artificial silk imparts great elasticity, and its coarseness gives stability of form without impairing the luminosity. The ash content of the textile yarn must be very low—not more than 0.02 to 0.03 per cent. Three hundred tons of thorium nitrate are consumed per annum in the mantle industry, which represents about 3300 tons of monazite sand. The by-products include over 1000 tons of cerium oxide, three tons only of which are required for mantle making. A ton of sand, costing $150, contains 2.5 mgrms. of radio-active mesothorium, of which 2 mgrms. (worth $150) are recoverable. Thus 6 grms. of mesothorium are available as a by-product, but much larger quantities will probably be required for therapeutic purposes. Since the mantle industry cannot absorb more thorium, the extraction of larger quantities of mesothorium depends on the profitable utilization of the cerium. Of the 1000 tons of cerium oxide now obtained, 200 tons are employed in the manufacture of sparking alloys for cigar lighters, etc. The cerium is obtained by electrolysis of the fused chloride. 300 tons more are used in the form of the fluoride for impregnating arc-light carbons. A considerable outlet for cerium compounds might be found in the weighting of silk. The dyeing and photographic industries take small quantities of cerium salts. In commercial mesothorium, 25 per cent. of the radio-activity is due to radium which cannot be separated. Weight

for weight, mesothorium is 300 times more active than radium, but it breaks down in a much shorter time. One of its most useful products is thorium-X which is 200,000 times more active than radium and can be obtained in the form of solutions of any desired strength. The γ-rays of mesothorium are distinguished by a very high penetrating power.

Surface Devitrification of Glasses. C. J. BROCKBANK. (*Trans. Amer. Ceram. Soc.*, XV, 600.)—The physical and chemical changes which may occur in the surface layers of glass on reheating from the solid to the plastic state are due to the volatilization of the alkalies and the consequent production of silicates of a higher silica content. If maintained at the critical temperature for several days, the change will proceed throughout the solid glass. As the soda-lime silicates are the most liable to this defect, they were investigated with regard to the influence of their chemical composition on devitrification. The softening point was determined by the distorted reflection of a pointed steel rod poised vertically on the heated glass, and the dimming point was indicated by the disappearance of these reflections, while the muffle was provided with a thermo-couple. The results show that magnesia, and alumina to an even greater degree, are beneficial constituents of glass. It is a decided advantage to use dolomite. Alumina, in addition to its influence against devitrification, in amounts above three per cent. greatly increases the viscosity of glass.

A 30,000-Kilowatt Turbine. ANON. (*Sci. Amer.*, cix, No. 22, 407.)—The Interborough Rapid Transit Company of New York City has recently placed an order with the Westinghouse Machine Company for a horizontal turbine of 30,000 kilowatts capacity. The feature of this particular unit is its division into two turbine elements; the high-pressure element being a single-flow turbine, operating at 1,500 revolutions per minute, and the low-pressure element being a double-flow turbine, operating at 750 revolutions per minute. The machine is of the reaction type throughout, and comparatively low blade speeds are involved.

Production of a Pink Vitrified Floor Tile. R. HEIDINGSFELD. (*Trans. Amer. Ceram. Soc.*, XV, 140.)—The tile body was vitrified at cone 11, and the best pink was obtained from a mixture of Fe_2O_3, 1, Al_2O_3, 90, and Cr_2O_3, 9 per cent. mixed as a stain with ten times its weight of the body-mixing: 64 per cent. of spar, 5 of flint, and 31 of kaolin. The pink thus obtained could be darkened to ruby by substituting 5 per cent. of calcium phosphate for 5 per cent. of alumina in the stain composition. This probably acted as a flux, producing at cone 11 a dark pink, which would have been produced without its use at a higher temperature.

Laminated Gears. ANON. (*Eng.*, xcvi, No. 2502, 790.)—A new method of making accurate gears is being developed commercially by Laminated Gears, Ltd., of Sheffield, Eng. The method is due to Mr. A. E. Terry and consists in constructing a spur-wheel or pinion by assembling together a number of discs of thin steel, in which teeth are formed by a stamping process. These stamping processes have been brought to a high pitch of perfection and it is claimed that very accurate gears can be rapidly and cheaply produced, while the use of thin plates facilitates the operation of case-hardening the teeth when it is desired. In assembling the discs, any errors of form can be distributed if need be, and successive discs are stepped forward by half the pitch. This gear runs very smoothly and silently. The makers claim that with these gears the noise is so reduced as to make them suitable for adoption where raw-hide pinions are now considered essential.

Gloves for X-ray Work. ANON. (*Sci. Amer.*, cix, No. 24, 45[illegible]—The protecting gloves generally used for X-ray work are ordinary gloves having laid on the back a layer of rubber containing lead, as lead is known to stop the rays. But this layer is somewhat stiff and lacks suppleness; moreover, only the back of the hand is protected, and the palm and sides which are often exposed to the rays have no shield to protect them from their action. A French inventor makes use of a fabric which is much more flexible, and protects the whole of the hand from the rays. This fabric is woven from silk which is heavily "sized" with a lead composition, so that it contains three times its weight of lead. This tissue has the advantage of being far more elastic than that previously used, and acts as a very good screen for the X-rays, especially when the back portion is reinforced. It will doubtless be very serviceable to operators, who always run the risk of severe burns.

Talc as a Body Material for Pottery. C. W. PARMELEE and G. H. BALDWIN. (*Trans. Amer. Ceram. Soc.*, xv, 532.)—Commercial talc may be either talc or steatite. Considerable quantities can be substituted for clay in bodies without affecting the working properties. Even in small quantities it has a decided influence in promoting translucency and whiteness of ware. Talc promotes vitrification, which proceeds slowly and without the sudden fusion caused by lime; it also increases the toughness of the body, as measured, by loss on abrasion.

Economy of the Dry Blast. J. VON EHRENWERTH. (*Iron and Steel Inst.*, May, 1913.)—Calculations showed that the percentage economy of fuel due to the reduction of the moisture of the blast from 15 to 5 grammes per kilo, without considering the consequent reduction of temperature of the waste gases, varied between 6 and 11; and that due to the lowering of temperature of the waste gases

between 3 and 15. The total economy was from 9 to 25 per cent. The economy of drying the blast is greater the lower the temperature of the blast and the higher the original temperature of the waste gases. As there is less fuel charged, the total volume of material, and hence the volume of blast, per unit of production is less; thus the blowing engine and stoves can cope with a larger production, and the furnace yield is increased. The temperature in the melting zone is raised, and not only is the melting accelerated but the silicon is increased and the sulphur lowered. The advantages are, however, dependent on local conditions being greatest in the case of furnaces working with high temperatures both of blast and waste-gas, as in the production of ferromanganese, ferrosilicon, or ferrochrome, and in localities where the atmosphere is moist.

The International Congress of Consulting Engineers.—The Second International Congress of Consulting Engineers will be held in Bern, Switzerland, July 15 to 22, 1914. The conferences will be held in conjunction with the Swiss National Exhibition. The preliminary announcement gives a list of the organization committee and rules governing membership. Efforts will be made to hold the Third International Congress at San Francisco in 1915, from September 20 to 25, and it will form a part of the International Congress of Engineers which has been arranged for that date.

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